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Particles and Fields—Interplanetary Space

5310 Cosmic Rays
AN ANALYTIC EXPRESSION FOR THE RADIAL DEPENDENCE OF THE DIFFUSION COEFFICIENT FOR QUIET TIME ENERGETIC HELIUM AND OXYGEN IN THE HELIOSPHERE
K.C. Hsieh and A.K. Richter (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau 3, West Germany)

Taking recent observations of the differential radial gradients and energy spectra of quiet time energetic particles of different energies and masses and over a large heliocentric radial distance from 0.3 to 18 AU into account, we show that the transport equation for these particles (Fokker-Planck equation) reduces to a first order differential equation for the radial diffusion coefficient, which then can be solved analytically. For energetic Helium and Oxygen nuclei we then discuss the radial dependence of their diffusion coefficient.
J. Geophys. Res., Blue, Paper 1A0639

5310 Cosmic Rays
RELATIVISTIC COSMIC RAYS AND CO-ROTATING INTERACTION REGIONS
S. P. Duggal (Bartol Research Foundation of The Franklin Institute, University of Delaware, Newark, Delaware 19711) B. T. Tsurutani, M. A. Pomerantz, C. H. Tsao, and E. J. Smith

Analyses of relativistic galactic cosmic ray intensity variations have been conducted to determine the nature of the modulations that are related to the presence of co-rotating interaction regions (CIR) in interplanetary space. The co-rotating interaction regions have been identified from the plasma and field observations recorded by Pioneer 10 and 11 spacecrafts during the period 1972-1974. This investigation has established that the nucleonic intensity recorded at the polar stations Thule and McMurdo decreases as the streams associated with the CIR overtake the earth. However, this modulation occurs only for those CIR associated streams in which a neutral sheet is imbedded. In contrast, geomagnetic storms are related to CIR-streams with or without neutral sheets. Taken together, these results suggest that the ostensible effect of CIRs on the intensity of high energy particles is primarily a consequence of drifts related to neutral sheets.
J. Geophys. Res., Blue, Paper 1A0646

5310 Cosmic Rays
COSMIC RAY GRADIENTS IN THE HELIOSPHERE AND PARTICLE DRIFTS
Gordon Newkirk, Jr. (Physics Department, University of New Hampshire, Durham, NH 03824) and John A. Lockwood

X-coronameter, solar wind, and neutron monitor data are used to estimate the latitudinal gradient of ~5GeV protons in the heliosphere at 1 AU during 1965 and 1975. The reversal of sign of the gradient between 1965 and 1975 and the strong positive latitudinal gradient in 1975 predicted by models in which drifts are dominant are not observed.
Geophys. Res. Lett., Paper 1L0905

5370 Solar wind magnetic fields
MAGNETIC LOOP BEHIND AN INTERPLANETARY SHOCK: VOYAGER, HELIOS AND IMP-8 OBSERVATIONS
L. Burlaga (NASA/Goddard Space Flight Center, Laboratory for Extraterrestrial Physics, Greenbelt, MD 20771) E. Sittler, F. Mariani and R. Schwenn

Magnetic field and plasma data from 5 spacecraft (Voyager 1 and 2, Helios 1 and 2, and IMP-8) were used to analyze the flow behind an interplanetary shock. The shock was followed by a turbulent sheath in which there were large fluctuations in both the strength and direction of the magnetic field. This in turn was followed by a region (magnetic cloud) in which the magnetic field vectors were observed to change by rotating nearly parallel to a plane, consistent with the passage of a magnetic loop. This loop extended at least 30° in longitude between 1-2 AU, and its radial dimension was approximately 0.5 AU. In the cloud the field strength was high and the density and temperature were relatively low. Thus the dominant pressure in the cloud was that of the magnetic field. The total pressure inside the cloud was higher than outside, implying that the cloud was expanding as it moved outward, even at the distance of 2 AU. The momentum flux of the cloud at 2 AU was not higher than that of the preshock plasma, indicating that the cloud was not driving the shock at this distance. It is possible, however, that the shock was driven by the cloud closer to the sun where the cloud may have moved faster. An extraordinary filament was observed at the rear of the cloud. It was bounded by current sheets whose orientations were preserved over at least 0.12 AU and which were related to the plane of maximum variance of the magnetic field in the cloud. (Shocks, solar wind magnetic fields, solar wind plasma, magnetic loop).
J. Geophys. Res., Blue, Paper 1A0759

5380 Solar wind plasma
INVERSE MAPPING OF SOLAR WIND FLOWS
V. Pizzo (High Altitude Observatory, NCAR, P.O. Box 3000, Boulder, CO 80307)

The widely-used constant velocity technique is capable of mapping solar wind structures seen near 1 AU back to the vicinity of the sun with only limited accuracy. This report points out that relatively sophisticated MHD numerical models can be applied to this 'inverse' mapping problem, promising better accuracy, especially in the region of the stream front.
J. Geophys. Res., Blue, Paper 1A0642

Particles and Fields—Ionosphere

5505 Airglow
OPTICAL OBSERVATIONS OF THERMOSPHERIC DYNAMICS AT ARECIBO
R. G. Burnside (Space Physics Research Laboratory, University of Michigan, Ann Arbor, MI 48109) F. A. Herrero, J. W. Meriwether, Jr. and J. C. G. Walker

Observations of thermospheric neutral winds have been made at Arecibo, Puerto Rico, by using a Fabry-Perot interferometer to measure the Doppler shift of the nighttime O(^{1}D) 630 nm emission. In general, the highest equatorward wind velocity is observed at about 2100 LST. The meridional wind velocity usually lessens as midnight approaches and sometimes, but by no means always, reverses after midnight. The magnitude of the equatorward velocity is greater in summer than in winter months. For winter and spring months, the zonal wind blows eastward throughout the night, with the velocity tending to decrease in a fairly regular fashion from about 125 m sec^{-1} at 2100 LST towards zero by 0400 LST. In summer the pattern is similar, but the eastward flow usually reverses earlier, and a westward velocity of some 50 m sec^{-1} may be attained by 0400 LST. Significant horizontal wind gradients are often observed in the meridional direction, but not in the zonal direction. Near midnight especially, during both the equinox and summer months, the equatorward wind is often greater to the north of Arecibo than to the south. We interpret this as being an effect of the passage of the midnight equatorial pressure maximum to the south of the station. Measurements of neutral temperature with the interferometer do indeed show that, between 0100-0200 LST, the neutral temperature to the south of Arecibo is enhanced by some 40°K over that to the north.
J. Geophys. Res., Blue, Paper 1A0610

5515 Auroras
THE AURORAL 2145Å FEATURE
A. Dalgarno (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138 USA) G.A. Victor and T.W. Hartquist

Laboratory data are used to argue that the excitation of the N II doublet near 2145 Å by electron impact on N_2 occurs through the ejection of an electron from the 2σg orbital. The cross section probably exceeds 10^{-18} cm^2, as is required if electron impact excitation of N_2 is the source of the auroral feature. By extrapolation along the isoelectronic sequence, we estimate a lifetime of 5.8 ms, in harmony with recent ab initio calculations. The auroral observations then imply a rate coefficient for quenching of $N^+(^5S^o)$ ions in the atmosphere of less than 10^{-10} cm^3 s^{-1}. (Atomic nitrogen).
Geophys. Res. Lett., Paper 1L0720

5520 Electric fields
FIELD LINE EQUIPOTENTIALITY AND ION-NEUTRAL COLLISION FREQUENCIES IN THE DYNAMO REGION DEDUCED FROM SAINT-SANTIN ION DRIFT MEASUREMENTS
C. Taïeb (CNET/Centre de Recherches en Physique de l'Environnement Terrestre et Planétaire, 38-40 rue du Général Leclerc, 92131 Issy-les-Moulineaux, France) M. Blanc

We analyse three-dimensional ion drift data from the Saint-Santin incoherent scatter facility to test experimentally the theoretical description of ion transport in the ionospheric dynamo layer, and to deduce electric fields and ion-neutral collision frequencies from the observed drifts.

Using a geometrical representation of the ion momentum equation, we show that at middle latitudes, because horizontal neutral wind influences ion motions both parallel and orthogonal to the field lines in the ionospheric dynamo layer, the information contained in a three-dimensional ion drift measurement is redundant, thus permitting to check the standard theoretical description of ionospheric electrodynamics in two ways. First, assuming a model ion-neutral collision frequency profile, one can deduce the north-south perpendicular component of the electric field function of height in the E-region from Saint-Santin drift data. We find that its altitude variations remain within the experimental uncertainty of the method, in agreement with the theoretical assumption of equipotential field lines.

Second, assuming that the electric field is constant in altitude, one can determine the ion collision ratio, or ratio of the ion collision frequency to the ion gyrofrequency, from a comparison of E and F region drift measurements. Daily median values of the ion collision frequencies, thus obtained, for each of the three seasons, are found to compare reasonably well with ion collision frequencies derived from the Jacchia neutral atmosphere model for the case of the equinox sample, but determinations for the other seasons are contaminated by a high level of measurement noise. (Electric field, collision frequency).
J. Geophys. Res., Blue, Paper 1A0649

Earthquake Seismograph Development: A Modern History—Part 1

Ben S. Melton

The years from 1948 through 1976 saw numerous changes in electrodynamic-type earthquake seismographs. During this period, these seismographs and their associated amplifiers, recorders, timing systems, and power supplies were adapted for worldwide service under many operating conditions. These developments required and led to a better understanding of the fundamental limitations on design, ultimately allowing small but adequately sensitive instruments to be built for installation in cased holes, thereby avoiding undesired local surface disturbances. The recording system developed within this period permits ready review and compact storage of seismological data.

Introduction

This history of development of modern earthquake seismographs covers the period from 1948 through 1976. This author's involvement with many decisions and occasional contributions is documented by personal records and some published reports. Some personal recollections of several individuals who were involved over the same period of years are included. All of the well-known American seismologists who were active during that period influenced and supported the developments by their advice, so the engineering advances described here were of a nature to forward the seismological art in a practical manner.

In writing such a history, one needs to compose a presentation easily followed by the reader rather than to follow a strict outline of dates. My choice is to present first the sequential history of seismometers, followed by that of amplifiers, then recorders, and finally, timing systems. This involves a slight repetition of material for the case in which a modulator has become a part of the seismometer, but in general, the sequence of developments was independent for seismometers, amplifiers, recorders, and timing systems. However, because of the length of this chronicle it has been separated into two parts. The first part will cover seismometers, the second, the remaining components. For the reader's convenience, the figure numbers will continue through the second part, which will be published in a forthcoming issue.

Prior to 1948, earthquake seismology in this country had an academic background. As a rule, a seismologist would purchase or have built a seismograph instrument or instruments suited to his interest in particular seismic phenomena. The different apparent surface speeds of seismic phases composed of compressive and shear waves enabled him to infer the distance of a given earthquake. Characteristically, one instrument or seismometer might have a spring-supported mass constrained to move vertically and with a natural period of about 1 s. A different instrument, or rather two more instruments, would have masses hinged on a vertical mast and constrained to move horizontally. These seismometers would be oriented so that one could respond to north-south motion, the other to east-west motion. Their periods would be on the order of 2 or 3, sometimes as much as 20 s. The short-period vertically responding instruments would best respond to the refracted compressive waves that travel through the earth's interior, while the horizontal mode instruments would respond to horizontal components of the longer-period shear waves.

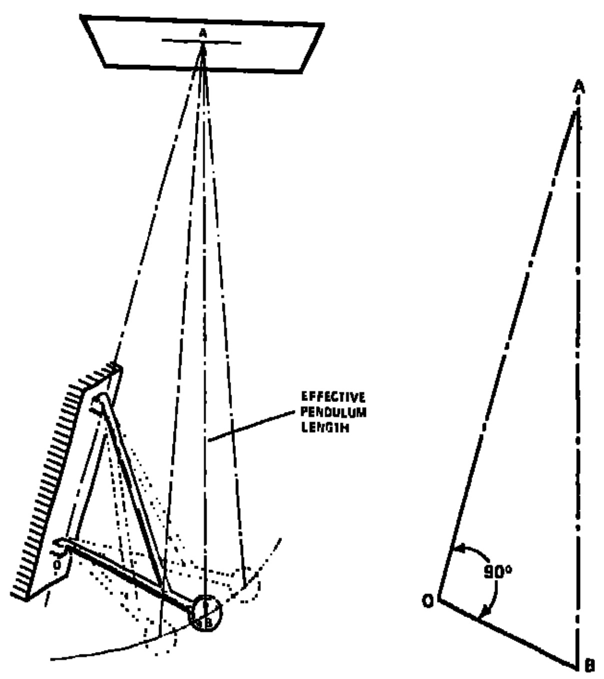

Fig. 1. Geometry of a horizontal-component seismometer, showing the relation of its hinge axis to the vertical.

To record distant earthquakes, the motion of each seismometer had first to be magnified by mechanical, optical, or electrical means. The early mechanical systems were easily analyzed in terms of response to earth movement, and these instruments were well covered by *Dewey and Byerly* [1969]. Their history of these instruments ended with the beginning of the 20th century. They mentioned the electrodynamic seismograph with galvanometer, which was introduced by *Galitzin* [1903], but did not discuss it.

When Prince Boris Borisovich Golitsyn (Galitzin) coupled the already well-known galvanometer to a seismometer pendulum through an electrical coil moving in a magnetic field, he laid the foundation for engineering development of the modern electrodynamic seismograph. Galitzin's galvanometer mirror deflected a light beam which was focused on sensitized paper that was carried on a rotating drum, thereby tracing a waveform that was related to the earth's vibration. Seismologists followed this earliest documented work by devising various models for different purposes. Among better known names within this country are those of *Wenner* [1929], *Benioff* [1932], and the W. F. Sprengnether Instrument Company, Inc., of St. Louis, Missouri, which built seismometers for various seismologists. In general, the electromagnetic seismograph in use until 1950 employed this photographic registration on film or paper wound around a slowly rotating drum. The drum was translated along its axis to allow several hours of recording on the same strip or sheet. This system, the electromagnetic or electrodynamic seismometer with its associated galvanometer and photographic recorder, provided high and controllable magnification at periods of interest. The seismometer could now be installed in a location less subject to nearby disturbances, and the recorder could be located more accessibly. Such was the status of most instruments in observatories before about 1950. Many observatories still use this arrangement.

However, the development of nuclear weapons after 1945, and national concerns about the possibility of clandestine tests of such weapons, led to demands for some means of detecting such tests, seismographic monitoring being one obvious choice. In 1947, Chief of Staff General Eisenhower assigned this task to the Signal Corps. With the reorganization that resulted from the emergence of the U.S. Air Force as a separate branch of the armed services later that year, the first secretary of defense, James Forrestal, reconfirmed the assignment to the Air Force Office of Atomic Energy. Funds became available to this office in 1948, and a staff of civilian scientists was assembled under a military structure. J Allen Crocker of that staff hired this author as a geophysicist in late 1948.

Review of available information on seismographic instruments in 1948 and 1949 showed that none was adapted for rapid manufacture and standardization, which would facilitate use by anyone other than an experienced seismologist. However, basic knowledge of mechanical and electrical design was available in some government laboratories. The David Taylor Model Basin in Carderock, Maryland, a Navy facility, had already designed some 'long-period' horizontal component seismometers for use in tracking storm microseisms. These were built by Reed Research Inc. of Washington, D.C. The Stanley Aviation Corporation of Denver, Colorado, was low bidder on a contract to develop 'short-period' three-component seismometers with associated amplifiers, etc., for the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Both of these systems drove Brush Development Company's multipen recorders through vacuum tube amplifiers.

Basic Mechanical and Seismological Problems

As distant earthquakes can produce ground vibrations with periods from a few tenths of a second to 20 to 30 s, seismometers have usually had natural periods within that range; it has been customary to have at least two sets, one set with natural periods of a second or two and another set with longer periods, sometimes 10 s or more. Two sets rather than one have been employed for sensing distant earthquakes because there exists a high and continuous vibration of the earth, called microseisms, in the period range from 3 to 8 s. These microseisms are caused by ocean wave action impinging on continental shelves.

In 1948 the microseisms were well known, but only rarely measured in amplitude at various periods and many locations, although the Navy had an ongoing study of their propagation speeds and directions relative to ocean storms. On the other hand, the natural period of the Navy seismometers was a handicap to the study of weak short- and long-period earthquake waves from great distances. Thus the scientific staff under Air Force auspices directed attention to separate seismometers for short and long periods.

Ultimately, the natural period designed into any earthquake seismometer depends upon the earth's gravity. Horizontal component instruments are designed like a 'garden gate,' that tends to swing shut because its hinge axis is aligned to intersect the vertical above the mass of the gate itself. Vertical component instruments must have a spring force that will neutralize the earth's gravity and allow the mass to have a rest position within a limited travel amplitude while sensing earth vibrations. Figure 1 shows the principle of the 'garden gate,' in which the force of the earth's field along AB is reduced by the cosine of the angle OAB. The spring force that supports the mass of a vertical component instrument should be linear with respect to spring extension, and for a simple coiled spring this becomes a large physical dimension for periods greater than a few tenths of a second. The length of a simple vertical coiled spring that supports a mass must be such that its extension $\bar{E}$ is given by the formula

$$E = gT^2/4\pi^2$$

where g is the acceleration of gravity, T is the period in seconds. Thus for a 10-s period the spring stretch E would be about 25 m. Although LaCoste had devised his long-period suspension by 1934, and LaCoste and Romberg analyzed it in their 1942 patent of a 'force measuring device,' it was not well understood by seismologists in 1948 or even much later, when LaCoste was building and selling practical gravity meters.

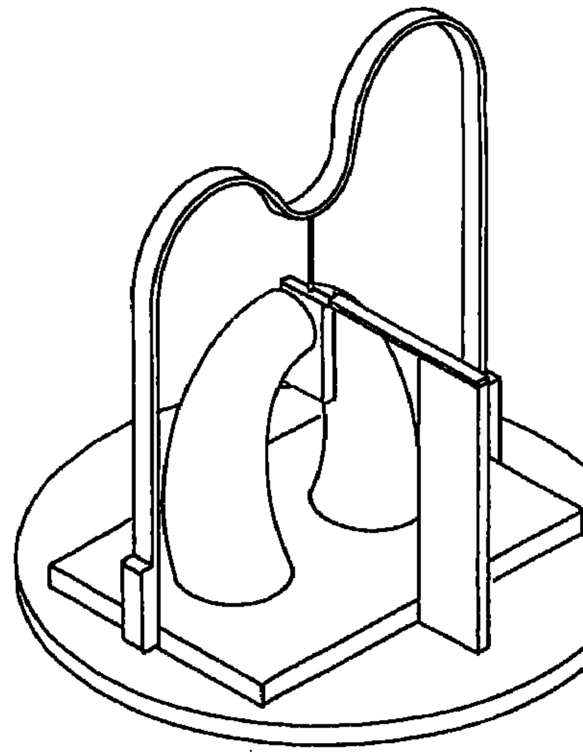

Fig. 2. Sketch of the spring suspension of the output coil of the Stanley short-period vertical-component seismometer.

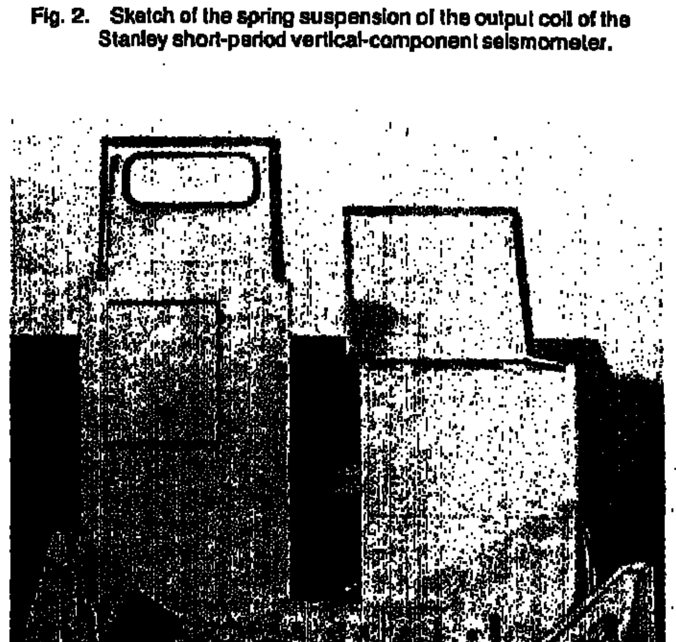

Fig. 3. DTMB horizontal-component seismograph system.

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Cover. Scanning electron photomicrograph of an experimentally produced fracture surface in an Arkansas River sand grain. Composition is quartz, except feldspar in upper left. Scale: photo width approximately 700 μ. Fractographic markings include cleavage hackles (upper left) and Wallner lines (center). (Photo courtesy J. J. Gallagher, Jr., Energy Resources Group, Cities Service Co., Tulsa, Okla.)

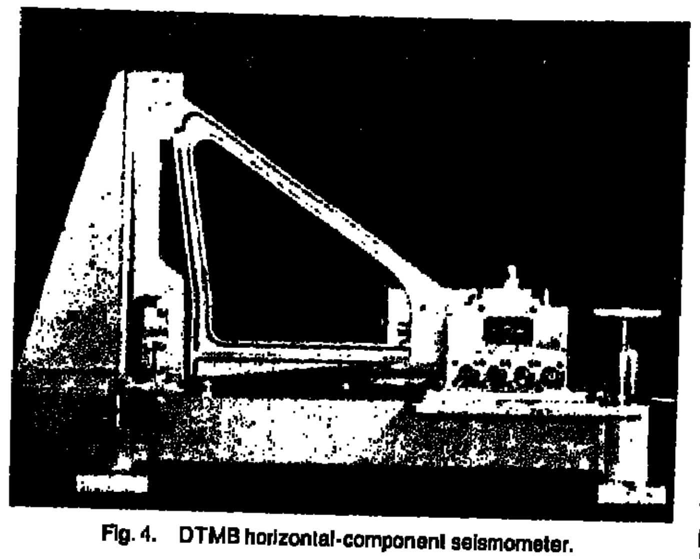

Fig. 4. DTMB horizontal-component seismometer.

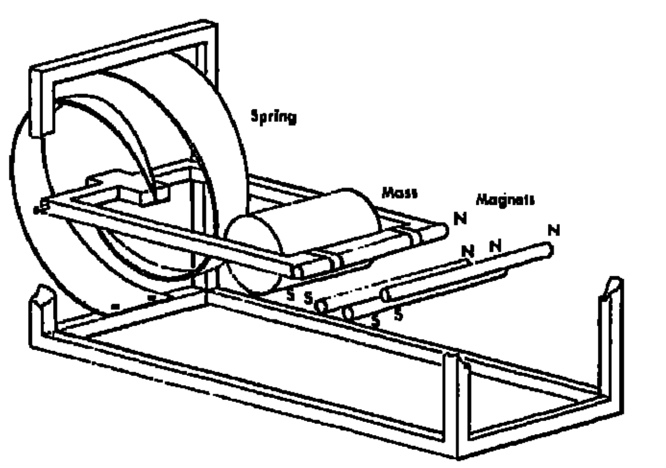

Fig. 5. Sketch showing principal construction features of the DTMB vertical-component seismometer.

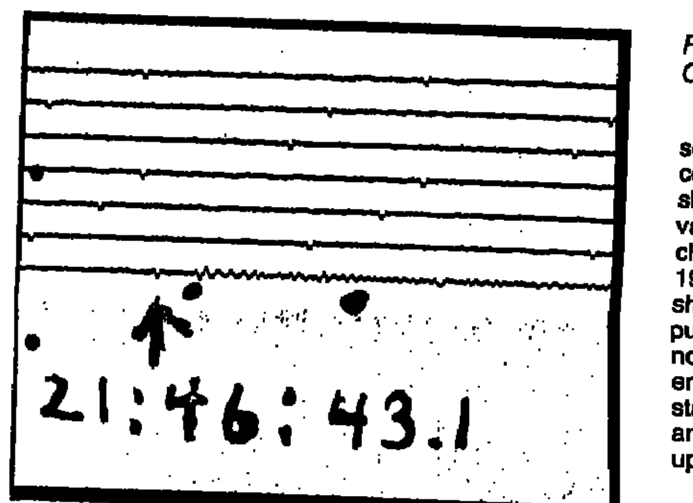

Fig. 6. Seismic record trace of the Eniwetok nuclear explosion of July 24, 1946, at 21 h 34 min 59.7 s GMT.

Early Designs of Sensitive Seismographs

The Stanley short-period seismographs and the David Taylor Model Basin (DTMB) long-period seismographs were available in 1948. The Stanley instruments provided vacuum tube amplification of the voltage generated by a coil moving in the flux field of a permanent magnet. The magnets used were surplus magnetron magnets. Use of these was a factor in allowing Stanley to submit the lowest bid to the Department of Terrestrial Magnetism (DTM). The vertical (component) Stanley seismometer used the coil as its mass. The impregnated coil was supported from a strip of spring phosphor bronze (later replaced by 'iconel') that was fastened rigidly at its ends but bent into a shape resembling a 'bishop's hat,' a name which stuck to it at the time. Figure 2 is sketched to show the essential parts of this device, which, by its nonlinear force, tended to keep its vertical dimensions within reasonable bounds while supporting the mass-coil. This arrangement was never successfully stabilized, however. The horizontal component Stanley seismometer was built on the garden gate principle. Figure 3 shows the DTMB assembled system. The DTMB seismometers did not generate a seismic signal from a coil moving in a magnetic field. Instead, they used a capacitance bridge, one arm of which was the capacitance between a 'condensor button' and part of the pendulum. Some mechanical damping was provided by a dashpot that contained damping fluid.

The capacitance bridge network was fed by 100 kHz from a crystal controlled oscillator and buffer amplifier. When the bridge was balanced—the pendulum presumably centered in its travel—there was no signal output to an amplifier-demodulator combination. Any displacement of the pendulum unbalanced the bridge, supplying a 100-kHz signal with magnitude presumably proportional to displacement and phase depending upon direction of displacement from the balance point. A phase-sensitive detector, or demodulator, provided a signal at seismic frequency. This seismic signal followed two paths. One was through amplifiers to the Brush recorder. The other path was through yet another amplifier to a positioning electromagnet whose field was arranged to oppose the field of a permanent magnet mounted on the pendulum. Such a negative feedback reduced the natural period of the pendulum, thereby reducing sensitivity at the longer periods by effectively increasing the passband for seismic signals. Figure 4 shows the DTMB horizontal component seismometer. The electromagnet feedback case is back of the pendulum in this photograph.

By mid-1949 the DTMB group, under George Cook, had built an experimental long-period vertical component seismometer whose principles are illustrated in Figure 5. The spring force here was applied as a torque at the hinge end of a long arm that supported the mass, and several fixed permanent magnets offered a measure of control and stabilization by opposing the field of a magnet mounted on the seismometer arm. The centering of the mass was aided by proper positioning of magnets below the arm, and the period was affected by the magnet horizontally opposite the arm, producing periods as long as 30 s or more. The torque assembly was comprised of strips of spring metal which had low-temperature coefficients of expansion and rigidity, but the system could not be stabilized for actual service and was never developed further.

One set of the DTMB horizontal component seismographs was put into experimental field service by Beers and Heroy, a partnership between Roland F. Beers and William B. Heroy, Sr., in Troy, New York. Of that organization, staff members active today include Jack H. Hamilton, Braden B. Leichliter, and Martin Gudzin, all currently associated either with Teledyne or Teledyne Geotech in Garland, Texas, hereafter referred to simply as 'Geotech.' Seismologist Carl Romney, a graduate student recommended by Perry Byerly, was with the Troy organization originally.

The DTMB seismographs were in the field near Troy, New York, and operating at the time of the magnitude 8.7 earthquake of August 15, 1950, which was located 28.5°N, 96.5°S (eastern end of the Himalayan range). But when word of the quake was received through Carl Romney, 'Brad' Leichliter visited the observatory and found the operator asleep. The excuse: 'When the pens went wild, I decided it was (instrument) noise and shut it down.' However, consideration of the logistics problems involved in supplying storage batteries for vacuum tube filaments plus large quantities of dry batteries for plate current resulted in discontinuance of the manufacture and development of both Stanley and DTMB instruments. This would have happened even had it been possible to improve them. Power supplies with long-term stability and which were fed from the ac power line were not available in 1948 and the early 1950's.

Reconsiderations of Practical Seismographs and Combinations

The disappointing experience with these efforts to create sophisticated seismograph systems led to reconsideration of commercially manufactured instruments. Investigation showed that a Benioff short-period seismometer, with galvanometric registration on film, located in California, had clearly recorded the Eniwetok nuclear explosion of July 24, 1946, that was known as 'Bikini-Baker.' The print of Figure 6 shows this record section on the lowest trace. The square pulses on all traces are 1 min time marks. This record was in no sense surprising, but its existence, and political expediency, suggested that the best course was to procure and install Benioff instruments as quickly as possible. Hugo Benioff and Francis Lehner of Lehner & Griffith allowed Geotech to update manufacturing drawings, and Geotech put both vertical and horizontal seismometers into production. These versions are shown in Figure 7.

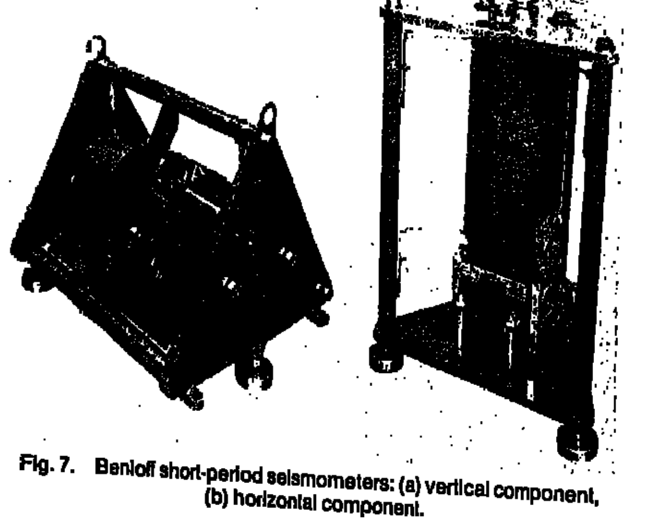

Fig. 7. Benioff short-period seismometers: (a) vertical component, (b) horizontal component.

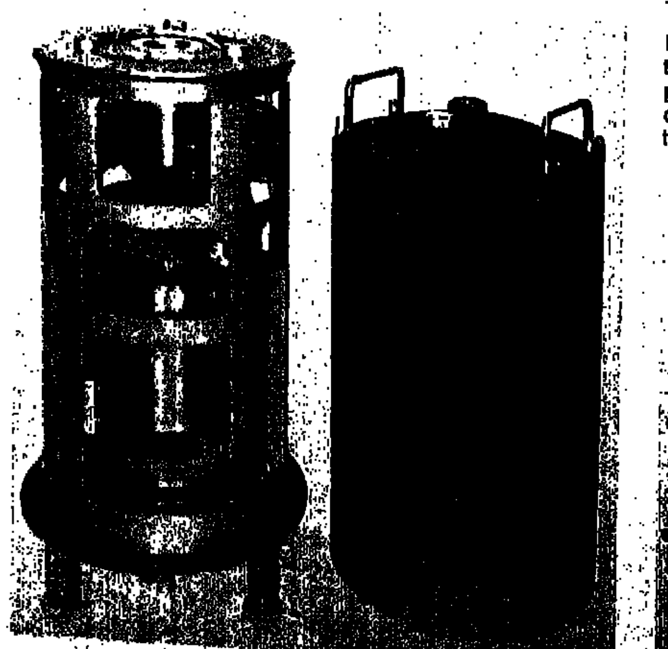

Fig. 8. Johnson-Matheson seismometer and case.

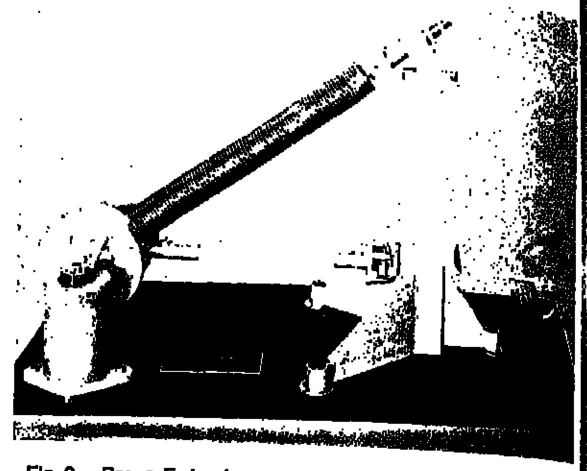

Fig. 9. Press-Ewing long-period vertical-component seismometer with LaCoste suspension.

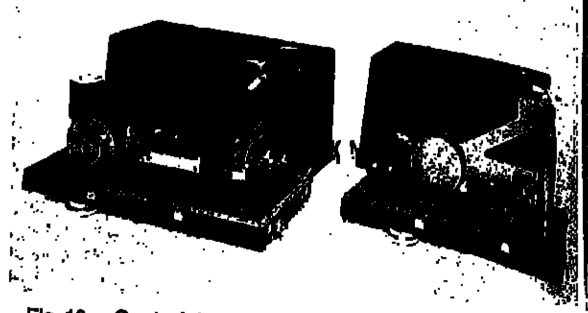

Fig. 10. Geotech long-period vertical- and horizontal-component seismometers.

Benioff's original paper, published in 1932, pointed out that the instrument's magnetic structure (technically, a 'variable reluctance' structure) had the effect of reducing spring stiffness, thereby shifting the natural period slightly above a half second. Also, that paper discussed the advantages of using a long-period (i.e., 14-s) galvanometer with his short-period seismometer. By 1957, Benioff had put in service a seismograph designed to respond to the normal dilatational modes of the earth's vibration. He housed one of his variable reluctance seismometers in a stiff cylindrical steel chamber to reduce its response to barometric pressure variations. To this seismometer he connected a galvanometer that had a natural period of approximately 10 min. The seismometer period was adjusted to about 2 s. The external critical damping resistance of the galvanometer was 135,000 ohms, and the transducer winding had a resistance of 135,000 ohms. To reduce the response to short-period waves, a capacitor of 200 μF was shunted across the transducer, followed by a 135,000-ohm resistor in series with the galvanometer. This arrangement makes the response constant to ground displacement within ±3 dB from 2 to 6000 s. When capacitor and resistor are removed, response to velocity is constant over the same range. However, today's negative attitudes about galvanometers have tended to close this avenue, even though it was investigated by *Wenner* [1929] and reinvestigated by the National Bureau of Standards (NBS) about 1960, in a study by D. P. Johnson and H. Matheson of the Bureau.*

In addition to their theoretical studies, Johnson and Matheson, with the aid of master machinist Henry A. Schmidt, also of NBS, designed a short-period vertical component seismometer in which the permanent magnet was used for the mass, while the electrical coil was mounted in the frame. Figure 8 shows this instrument. A period of 0.8 s was achieved by supporting the magnet mass from three levers, which reduced the force of very stiff springs. The springs were made very compact and could be given a prestretch in their normal position. The effect of spring stiffness was reduced by a factor of 10 in this manner; this was equivalent to making the springs 10 times as long. These instruments were quite rugged, and some of them eventually replaced the vertical component Benioff seismometers. Some details of this instrument were shown and discussed by *Melton and Johnson* [1962].

*NBS Report 7454 was first issued in 1962. The final document, NBSIR 76-1089, was issued in 1976; but this report never entered the public literature because its authors declined to discuss earlier papers covering the same material. In lieu of such discussions they defined all of their variables and included those of the earlier literature, where appropriate, for the reader's reference.

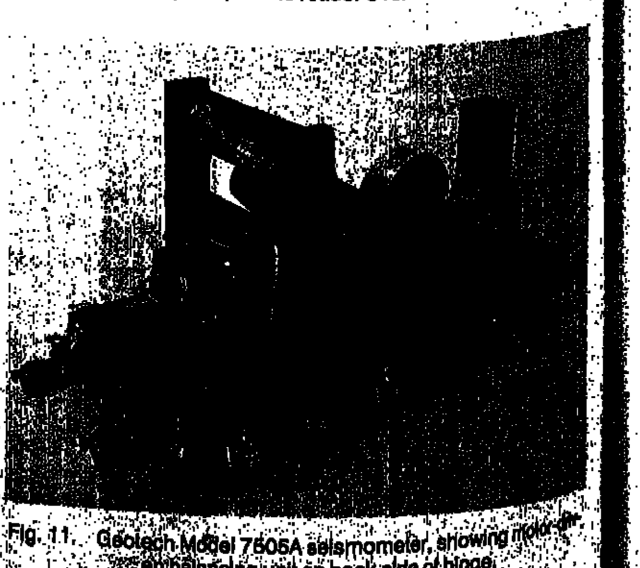

Fig. 11. Geotech Model 7505A seismometer, showing motor-driven balancing unit on back side of hinge.

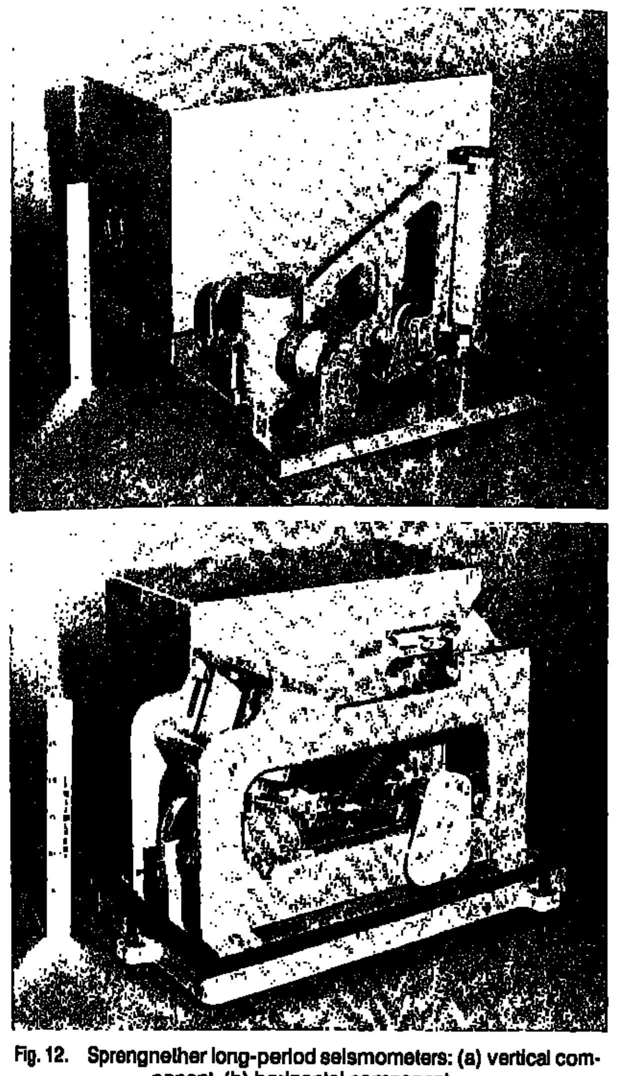

Fig. 12. Sprengnether long-period seismometers: (a) vertical component, (b) horizontal component.

During the study of this seismometer and others there was much discussion of how small a mass could be adequate. Clearly, the greater the mass, the more energy available from earth vibrations to be recorded. Also, the instrument self-noise power was believed to be inversely proportional to the mass. Both considerations suggested that there should be a minimum acceptable mass. Wolf discussed this in 1942, Byrne in 1961, and Johnson and Matheson about the same time. With these studies and other factors in mind, the 18-kg mass of the NBS seismometer was thought to be just adequate. Only years later did review of earlier published theory, by O. D. Starkey of Geotech, *Block and Moore* [1966, 1970], and the present author, establish the fact that the damping energy was the only source of thermal noise—the ultimate limit of useful sensitivity.

Of course, the total damping energy depends on the mass, so if the mass is very small, the absolute damping must be very low—effectively, the 'Q' must be very high. Also, it should be noted that the external damping power of an electrodynamic seismometer provides the only means of registering its motion or, equivalently, transferring information outside the instrument. The internal damping, including coil losses, does not transfer information. This theory and supporting earlier experiments were covered in a review paper by *Melton* [1976].

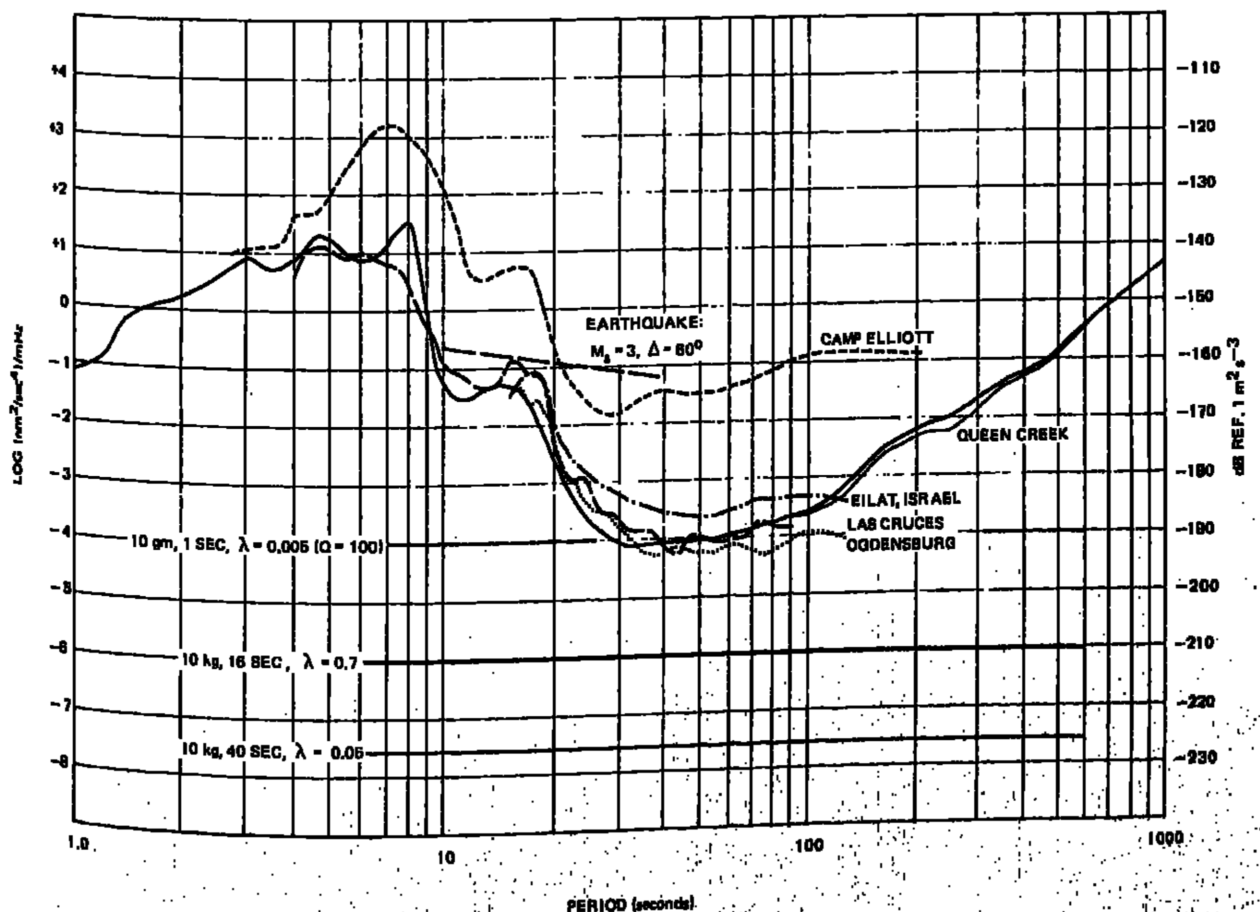

Fig. 13. Medium- and long-period spectra of earth noise plotted as squared acceleration per millihertz. The Queen Creek spectrum, after *Fix* [1972], is shown with two branches, the thin line lower branch representing the noise after subtraction of the measured instrumental noise included in the upper branch. Elsewhere along this curve the instrumental noise is a negligible portion of the energy represented. The Camp Elliott curve, after *Haubrich and MacKenzie* [1965], represents data from a southern California site about 20 km from the West Coast. References for the other curves are as follows: Las Cruces, New Mexico, *Trott* [1965]; Ogdensburg, New Jersey, *Savino et al.* [1972]; and Eilat, Israel, *Murphy et al.* [1972]. Thermal acceleration energy for several assumed seismometers is shown by the horizontal solid lines, and a proposed frequency plot of an earthquake with surface wave magnitude of 3 at 60° epicentral distance is included in order to show the relation between earthquake and noise energy.

Earthquakes and explosions both produce seismic body and surface waves; however, explosions generate relatively weaker long-period surface waves than do earthquakes. Thus to distinguish between earthquakes and explosions, long-period seismometers are desirable in association with short-period seismometers, but experience with the DTMB instruments discouraged development until *Ewing and Press* [1953], at the Lamont Geological Observatory of Columbia University, put into service a long-period vertical component seismometer that was built by Lehner & Griffith of Pasadena, California. Figure 9 shows this instrument, which was compensated for varying air buoyancy by an outrigged hollow sphere which had a volume equal to that of the seismometer's inertial mass. This instrument employed the LaCoste 'zero-length spring' suspension, thereby emphasizing its practicality. However, the seismometer was not shielded against air currents or insulated against temperature changes.

The need for temperature stability and insensitivity to air currents and barometric pressure changes called for an enclosed design for production. Accordingly, Geotech provided a design with a base and an airtight heavy case of Mehanite, a cast-iron alloy, which was clamped into a gasket around the perimeter of the base. The long-period vertical component was manufactured as Geotech Model 7505A. The associated horizontal component was Model 8700C. Both models are shown in Figure 10. The vertical component shown in Figure 11 has a balancing weight whose position can be changed by a motor drive that adjusts the mass 'rest position' to its center of travel. This model worked well at natural periods up to 15 s, but many instruments were unstable at periods greater than 20 s, chiefly because the LaCoste design was neither well understood nor well executed, and partly because of unsuspected paramagnetism of the electrical coil form, which was later corrected. These instruments were put in service late in 1962. The problems with these instruments resulted in publication of the *Melton* [1971] paper on the LaCoste suspension.

Sprengnether also built modern vertical and horizontal long-period seismometers, which are shown in Figure 12. In a well-protected environment these instruments serve as well as those of Geotech. In 1962, Sprengnether long-period vertical and horizontal component seismometers were installed as part of the World-Wide Seismograph System operated by the Coast and Geodetic Survey of the U.S. Department of Commerce. The vertical seismometers have a temperature compensator to adjust for gradual temperature changes, and both vertical and horizontal instruments are provided with metal covers with heaters and expanded polystyrene covers over the metal. These covers are not sealed however.

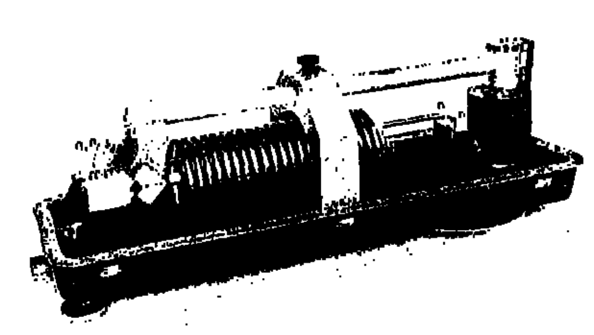

Fig. 14. Melton variable period seismometer.

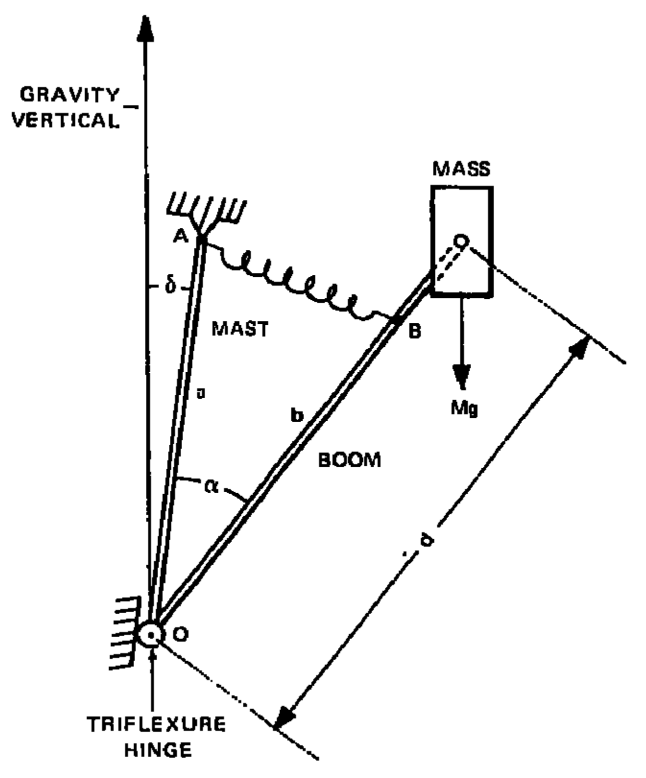

Fig. 15. LaCoste suspension as employed in the symmetrical triaxial seismometer; δ represents the angle of tilt.

Justification of the Mass Requirement for the Electrodynamic Seismometer

Throughout the period covered by this history, justification of the magnitude of the seismometer's inertial mass was a major concern. The mass had to be sufficient to deliver adequate energy for recording minimal earth vibrations. On the other hand, an oversize mass would increase problems of handling and shipping.

In 1963, using NBS Report 7454 as the reference, I made calculations to determine the minimum acceptable mass for a seismometer designed to detect weak long-period earthquake waves. The practical example taken was a 10-kg mass seismometer, which had a natural period of 15 s, closely coupled to a galvanometer that was recently designed by Forest K. Harris of NBS. That galvanometer had a natural period of 100 s and a moment of inertia of 4×10^{-6} kg m^2, and it was to be used in a phototube amplifier, a device which will be described in part 2 of this history.

In NBS 7454, ω_o, ω_g, and ω_m refer to the natural angular frequencies (radians per second) of the seismometer, galvanometer, and geometric mean of these frequencies $(\omega_o \omega_g)^{1/2}$, respectively; ϕ is the ratio ω/ω_m, where ω is the variable; λ_o, λ_g, and λ_m refer to fractions of critical damping for the seismometer, galvanometer and geometric mean $(\lambda_o \lambda_g)^{1/2}$, respectively; y is taken as earth displacement, and θ refers to the angular deflection of the galvanometer coil, so the fraction y/θ represents the earth displacement in meters per radian of coil deflection. Similarly, a fraction M/K is the ratio of seismometer mass to galvanometer moment of inertia.

Equation (6.3.22) in NBS 7454/NBSIR 76-1089 is

$$4\lambda_m^2 M/K\,(y/\theta)^2 = \phi^{-6} + \phi^2 + B^2 - A^2$$

where

$$A^2 = 2(\omega_g^2 + \omega_o^2)/\omega_m^2$$

and

$$B = (8 + A^4)/8A$$

As all quantities on the left side of (6.3.22) are real and positive, physical reality demands that the right side must be positive for all values of ϕ. The minimum value of $\phi^{-6} + \phi^2$ occurs at $\phi = \sqrt[8]{3}$ and is $4\sqrt[4]{3}/3$. For the problem at hand we can take ω at midband, so that $\phi = 1$. Then, substituting the angular frequencies, we find that $A^2 = 13.64$, $B^2 = 43.13$, so that

$$4 \times 0.8^2\, M/K(y/\theta)^2 = 2 + 43.13 - 13.64 = 31.49$$

and

$$y = 3.51\,\theta\,(K/M)$$

Substituting the seismometer's 10-kg mass and the galvanometer's moment of inertia 4×10^{-6} kg m s^{-2}, we obtain $K/M = 10^{-7}$, so that

$$y = 2.22 \times 10^{-3}\,\theta \text{ meters}$$

Experience had shown that we could observe and record a galvanometer angular deflection of somewhat less than a microradian by using a phototube amplifier with a good power supply. Taking $\theta = 1 \times 10^{-6}$ rad, we have $y = 2.22 \times 10^{-9}$ m at a period of 38.7 s.

When the above calculations were made, there was little information on the expected amplitude of microseismic noise at the longer periods. The data of *Trott* [1965], *Savino et al.* [1972], *Murphy et al.* [1972], and *Fix* [1972] were not available. These data were reviewed and collated by *Melton* [1976], and it is interesting to reexamine the choice of a 10-kg seismometer mass with the long-period galvanometer, in light of the later information.

Unfortunately, the spectral analysis presentation of a statistical sampling procedure masks the fact that at any given time the microseisms are nearly sinusoidal and mostly at one period. Similarly, earthquake waves usually have a maximum amplitude at some period that changes slowly, and it is this amplitude upon which detection depends. Therefore, we need to realize how microseisms over a narrow band are translated into a statistical value taken over a long time.

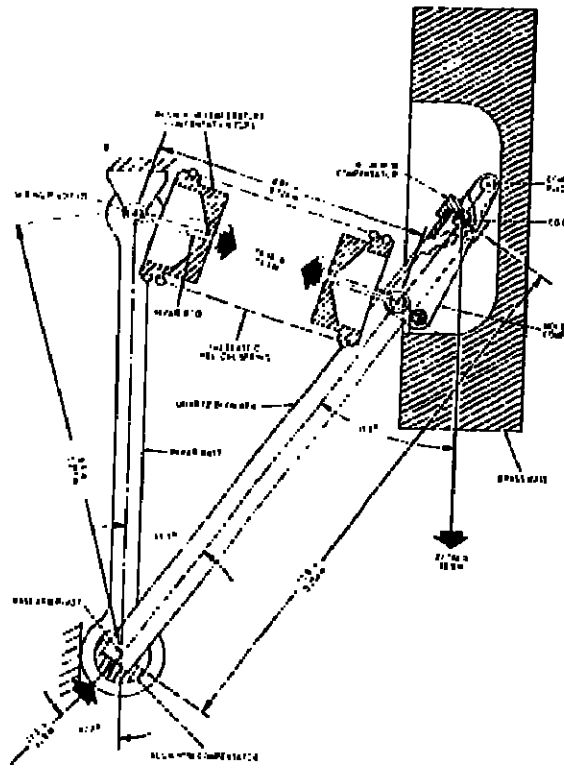

Fig. 16. Construction of La Coste suspension in one element of the triaxial seismometer.

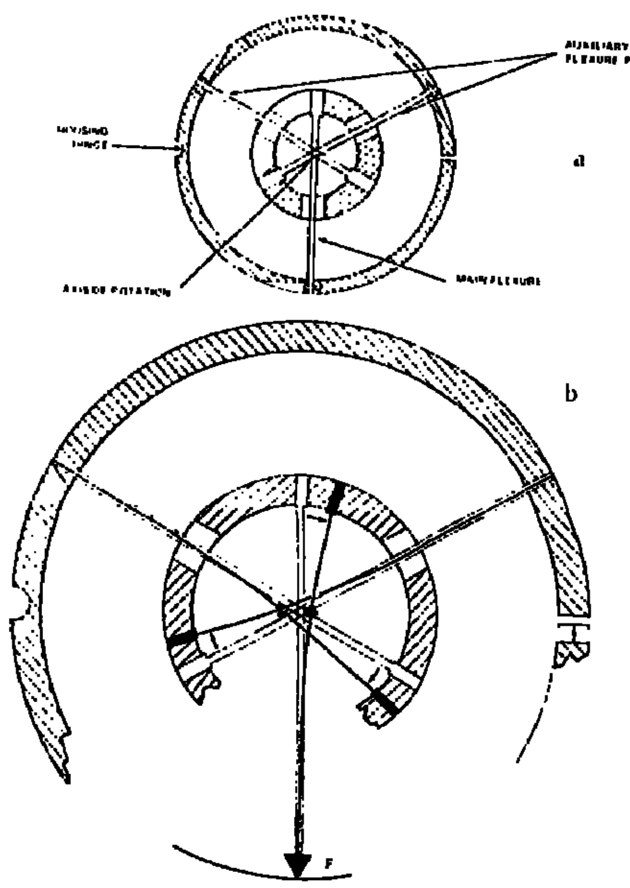

Fig. 17. (a) Basic configuration of triflexure hinge. (b) Introduction of force couple as inner member is rotated. Forcing open the outer housing at the slit on the right produces a tension force *F*. As the crossing point of the flexures moves away from the central axis, the force *F* tends to produce further rotation. The net result is to increase the seismometer natural period.

Consider Figure 13, which is reproduced from *Melton* [1976], and examine the region which shows curve maxima from 12 to 18 s. This curve should be interpreted simply as picturing a high probability that nearly sinusoidal microseisms will appear in this band, and by the same token they reduce the probability of earthquake wave detection in this same band. As we cannot validly reduce any statistical value of average energy to some specific value of energy at a single frequency, we must choose a bandwidth for conversion purposes. Based on comparisons of early visual measurements of microseismic amplitudes to the later statistical frequency analysis, my compromise choice is one-third octave.

Therefore, in the passband from 15 to 100 s, microseisms at 20 s or less should reduce the probability of detection over, say, a one-third-octave band centered at 17 s, 13.6 mHz. Taking an arbitrary value 1×10^{-1} (nm^2 s^{-4})/mHz, we have for one-third octave a mean square acceleration of 1.36 nm^2 s^{-4} and an rms acceleration of 1.17 nm s^{-2}, which corresponds to an rms amplitude of 2.72 nm at 17 s or a peak-to-peak amplitude about 3 times that value, or 8.15 nm.

Thus, if we accept a detection amplitude value of 2.22 nm over a *flat* passband from 15 to 100 s, we can conclude that the seismometer-galvanometer combination considered above has a high probability of having an adequate detection capability. However, in any real system the seismometer would be connected to the galvanometer through a resistive network that has some minimal loss, so prudence suggests that choice of a much smaller seismometer mass would not be advisable unless a galvanometer that has a lower moment of inertia were chosen also. For example, a Lehner & Griffith galvanometer Model GL-281 has a moment of inertia of 2.6 $\times 10^{-7}$ kg m^2.

Earth Noise Studies

As late as 1958 the seismological literature disclosed very little information on the amplitude of microseisms and cultural noise relating to geology, geography, time of year, or frequency of occurrence. However, in 1949 the Naval Ordnance Laboratory (NOL), located in White Oak, Maryland, was assigned to investigate these phenomena. No instruments were available for this study, so a laboratory group under the direction of J. V. Atanasoff, later directed by Ben Snavely, undertook to build small vertical and horizontal component seismometers for field deployment. These little seismometers, designed to go down a hole, used masses of about 100 g. Most of the suspended mass of each instrument was in a flat plate centered between two fixed plates, and the combination formed part of an electrical bridge that controlled the phase of a high-frequency carrier current, which was amplified and demodulated to give the low-frequency seismic signal output. The mass/plate of the horizontal component instrument was mounted on the top end of a thin flat spring. The vertical component mass/plate was also attached to a flat spring member, but a vertical coil spring was added to offset gravity. Both components had a natural mechanical period of about 1 s. A patent issued to Atanasoff and Kolsrud in 1956 reveals the details.

These instruments employed electrostatic forces to modify their response. A controllable dc potential difference between moving and fixed plates served to decrease the effective spring rate (restoring force), thus increasing the period to several seconds. Biasing this potential in favor of one or the other fixed plate served to recenter the movable plate. This recentering bias was provided by a long time-constant (~200 s) integration of the demodulated signal output, thereby reducing long-term drift. The demodulated signal output was also differentiated and fed back to provide controllable damping. The amplified signal output of each seismometer drove a galvanometer that deflected a light spot on photographic film, which was translated to provide the time axis. Also, the amplified signals were fed to Esterline-Angus chart recorders to monitor seismometer operation.

The NOL seismographs were deployed late in 1949 and were operated by military personnel through much of 1950, serving to relate microseisms of different frequencies to different times, as oceanic storms varied conditions of generation. However, these instruments were critical in adjustment, both mechanically and electrically, and not well suited to unattended operation. Also, their locations were restricted because they had power supplies that required connection to a commercial power line.

As experience was gained in siting seismometers for earth noise studies, and as more observatories were set up at numerous geologic locations, the construction of seismometer vaults was found to be important. Finally came the realization that even a concrete vault beneath the surface required a means of entrance which, if part of the structure, coupled the entire vault to the surface of the earth, thereby transmitting surface disturbances to the seismometer. Therefore, consideration was given to designing seismometers that could be put down a deep hole and adjusted, as necessary, by remote controls.

Accordingly, efforts to measure local earth disturbances as a function of depth were begun under a contract with United Electro Dynamics Corp. (UED) to put a seismometer at different depths in some abandoned oil well hole and to measure the noise at each depth in comparison with the noise at the surface. Shell's Government No. 1 well near DuBois in Fremont County, Wyoming, was chosen for this study, which began in late 1958. Many troubles were experienced with the instrument sent downhole, and the mud level sank continually. Only in 1960 were results obtained that seemed to indicate the expected reduction of noise as compared with standard instruments installed on the surface near the well. The well study was terminated in April 1960, but John Woolson of UED made further noise measurements for various geological surface conditions and sites for a number of months thereafter and on into mid-1961. Also, there were several attempts to correlate microseisms between sites separated by about a half kilometer or more. Spectral analysis was done by analog methods, by moving a filter band over a repeated sample of the noise on magnetic tape, this at higher tape speed in order to bring the signals into the audio band.

The well measurements were only the forerunners of later studies too extensive to discuss at length. In mid-1962 a variable reluctance seismometer, based on Benioff's design, was devised specifically to lower into deep wells for these studies.

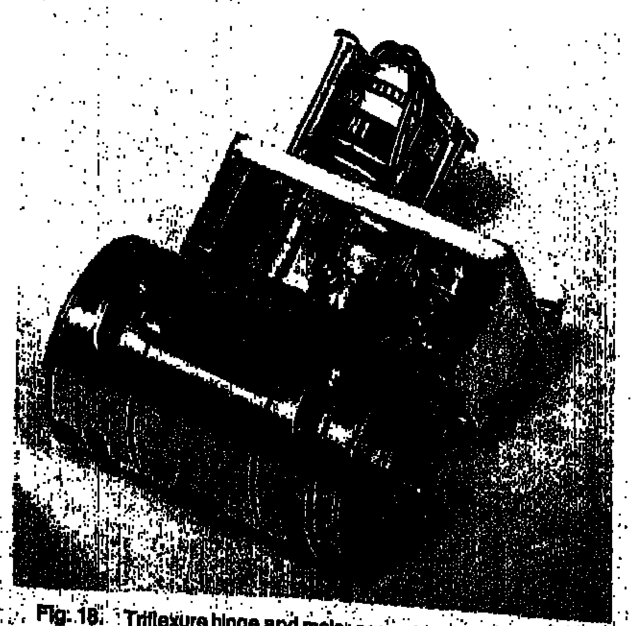

Fig. 18. Triflexure hinge and motor assembly. The reversible motor serves to adjust the tension *F*, shown in Figure 17, thereby controlling the seismometer period.

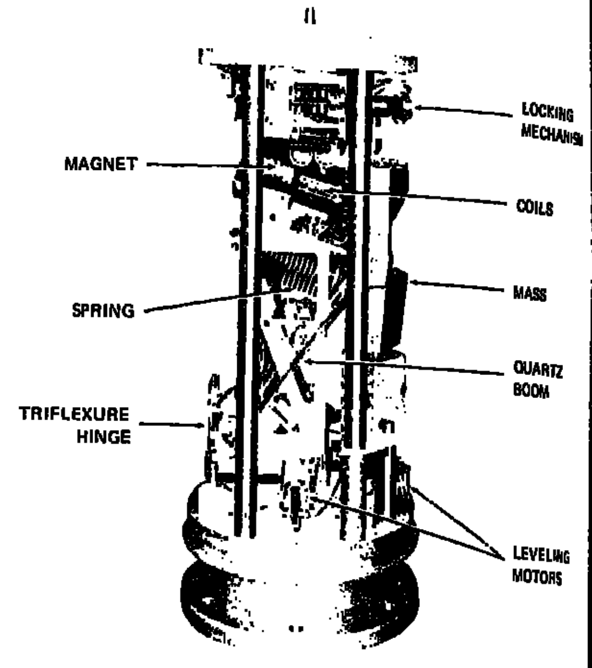

Fig. 19. Single module of the triaxial seismometer.

This instrument had a 100-kg mass and provided sufficient electrical output to ensure adequate sensitivity for measuring a very low noise field at great depths. The first well surveyed, Magnolia's Trigg No. 1, was located in the northeast part of Tarrant County, Texas, on the present site of the Dallas/Fort Worth airport. The well was about 3000 m deep, bottomed in limestone.

The Variable Period Seismometer—Its Concept and Use

In 1959 the author suggested, with a construction sketch, that a variable period seismometer be devised for use by any seismologist for his particular interest. The concept was to provide the critical parts unassembled, to be put together by the individual seismologist. However, funds were unavailable until later, when discussions of the atomic test ban took place and the USSR representatives offered some of their seismometers for comparison. As there were no comparable American seismometers available, funds were provided, and the Melton seismometer (Figure 14) was created. In this seismometer the 5-kg mass can be moved to or from the hinge, and the spring tension can be adjusted by stretching or relaxing the spring. A steel tape attached to the spring is wound on or off a drum through a worm and gear mechanism for this adjustment. The natural period is variable from 0.5 to 7 s, while the electrical circuit resistance required for damping remains nearly constant. *Hamilton and Stephens* [1962] mention that this instrument was installed at the Dallas Seismological Observatory at Southern Methodist University (SMU) to provide a flat "velocity" response over the period range from 1 to 100 s.

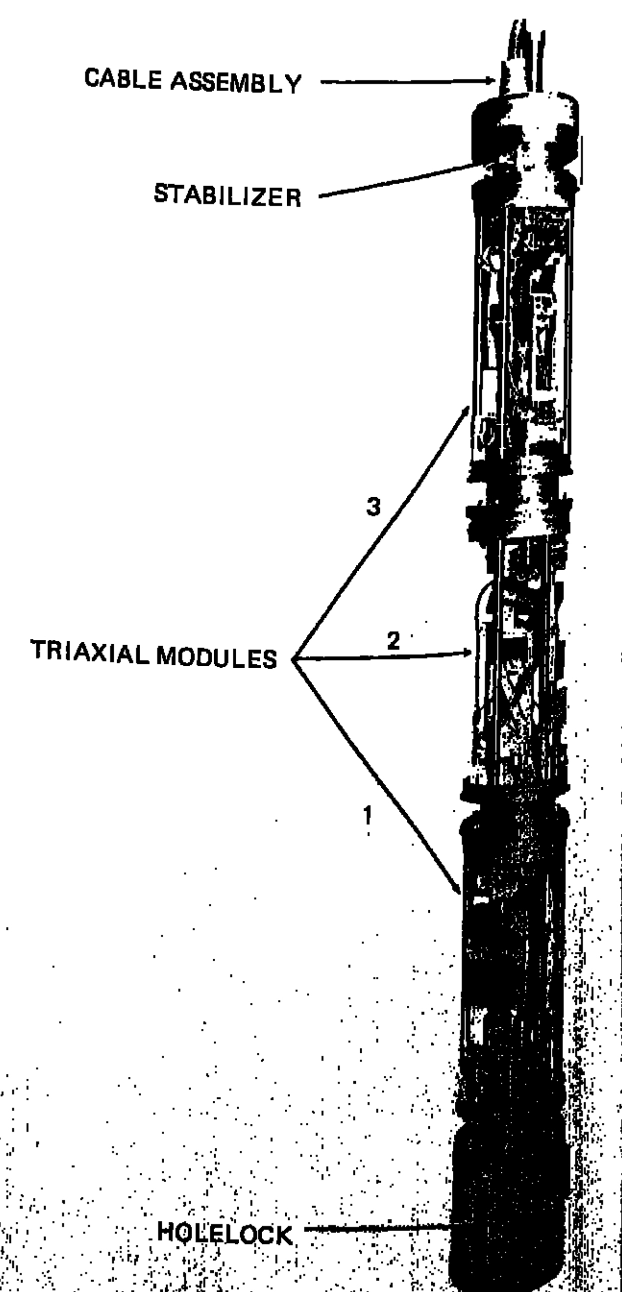

Fig. 20. Uncased assembly of the three modules of the triaxial seismometer, together with a holelock mechanism below and stabilizer above.

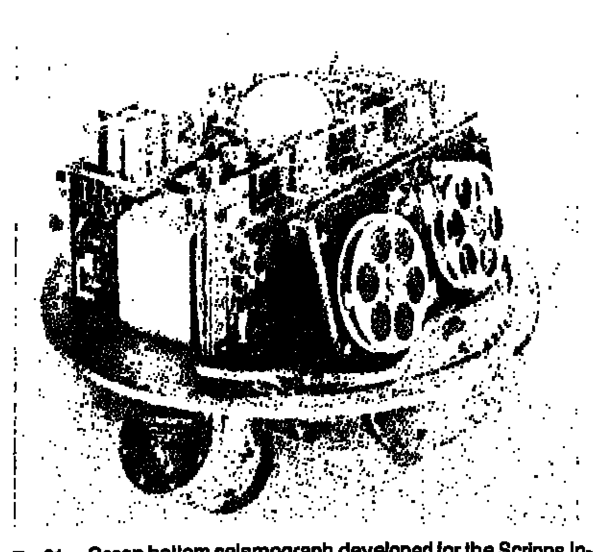

Fig. 21. Ocean bottom seismograph developed for the Scripps Institution of Oceanography.

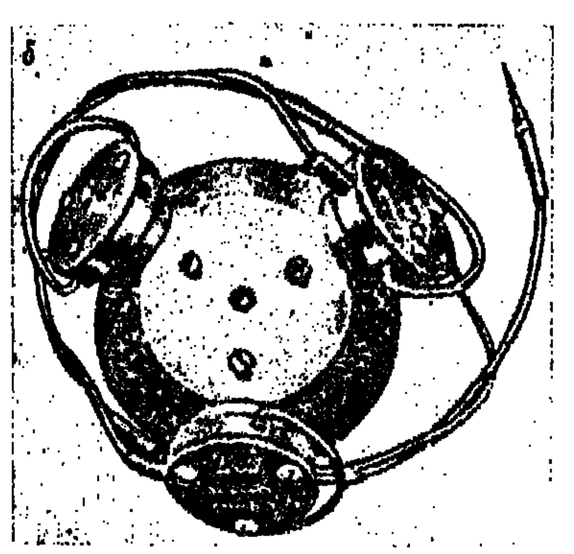

Fig. 22. Russian geophysical prospecting seismometer showing symmetrical triaxial arrangement of three of its sensors.

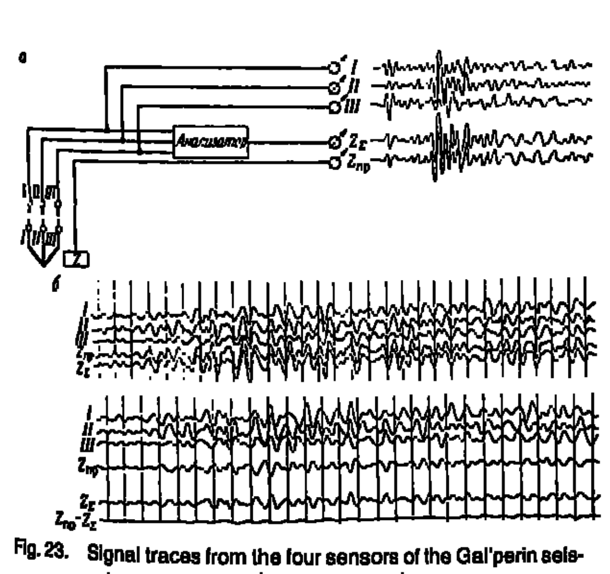

Fig. 23. Signal traces from the four sensors of the Gal'perin seismometer arrangement.

The Symmetrical Triaxial Configuration

Emphasis on adequate identification of long-period earthquake waves influenced the next development. The instrument was described and patented as an 'Angular Composite Seismometer,' but it became known as the 'Symmetrical Triaxial Seismometer.' In such an instrument the orthogonal directions of response form equal angles of about 55° with the vertical. These orthogonal directions permit sensing acceleration components that can be rotated algebraically to the conventional horizontal and vertical directions, provided the physical orientation of the instrument is known. The advantage of such an arrangement is that all three spring-mass systems are designed identically, giving greater assurance of matching characteristics. Also, as the arm carrying each mass is within about 35° of the vertical, the horizontal dimension can be less. Then stacking the three elements vertically permits a slim design, suited to putting down a hole.

My notes show that this composite seismometer was described to an associate on March 7, 1960. The ultimate mechanical design by Burnard Kirkpatrick of Geotech was underway in 1966, and an array of these instruments was being installed near Fairbanks, Alaska, in late 1968. The patent was filed in 1963 and issued December 7, 1965. The individual element masses were 10 kg because we had no assurance at the time that a lighter mass would be adequate. Each LaCoste suspension was designed and adjusted to the 'infinite period' position. Then the period was adjusted by changing the tension on a special triflexure hinge by way of a motor drive. Figure 15 diagrams the LaCoste suspension. The angle δ is zero for 'infinite period.' Figure 16 shows the basic construction of one element. Figure 17 illustrates design principles of the triflexure hinge. Figure 18 shows the hinge and motor assembly. A more complete description is given by *Melton and Kirkpatrick* [1970]. *Weinstein* [1965] discusses hinges of this general type as 'flexure pivot bearings.'

Figures 19 and 20 show a single module and an uncased assembly of three modules with holelock underneath and a stabilizing device at the top. These instruments showed greatly reduced response to local surface disturbances caused by wind and atmospheric pressure variations, even though in some installations the depth was much less than planned, because of drilling problems.

The symmetrical triaxial configuration was incorporated into an ocean bottom seismograph developed for the Scripps Institution of Oceanography by Earth Sciences Division, Teledyne Industries. Figure 21 shows the uncased assembly.

The symmetrical triaxial principle has also found its way into geophysical prospecting. *Gal'perin* [1977] has published a book which describes a polarization scheme of recording all types of waves simultaneously. In this scheme, four sensors are used. Three of them are oriented triaxially, as suggested in Figure 22. A fourth sensor responds as an independent vertical component. Figure 23 shows signal traces from these elements. Trace Z_Σ is evidently the effective vertical formed by direct summation of the triaxial component signals, while Z_{np} is the independent vertical signal. The Z_{np}-Z_Σ trace, if quiet, indicates a true amplitude match of the vertical component signal amplitude to the signal composed of the triaxial sensors and implies proper calibration of all sensor outputs.

Principles and Practices for a Radically Different Seismometer Design

Even as the symmetrical triaxial was being developed and put in service, a new concept of mass-thermal noise relationship was evolving. The realization that the thermal noise of a seismometer depended on its damping losses (rather than on its mass) suggested that a much lower mass and smaller seismometer could be devised, provided that amplifiers could compensate for reduced seismometer outputs. Briefly stated, the thermal noise (force) of a periodic system, electrical or mechanical, resides in its lossy elements. The system oscillations indicate the *presence* of some force, including thermal noise, but the amplitude of mass (or spring) oscillation is only a *measure* of energy, not the energy source itself.

O. D. Starkey of Geotech reviewed the work of *McCombie* [1953], *Milatz and van Zolingen* [1953], and *Milatz et al.* [1953], and by 1966 had composed a long handwritten treatise which included a 31-page section on 'Active Damping in Seismometer-Amplifier Combinations.' *Block and Moore* [1966, 1970] showed how active damping could be applied in designing an accelerometer, and I became fully aware of the principles in April 1970 when called upon as a consultant to evaluate the Block-Moore instrument. Essentially, the proposal was to provide a very small quartz seismometer with the desired damping—say, 0.7 critical—by applying negative feedback force to the mass, proportional to velocity, rather than using loss damping of any nature. The little mass would be part of a capacitance bridge modulator to provide an electrical output as the mass moved. A general discussion of this arrangement follows.

We have noted that the electrical load of a conventional electrodynamic seismometer provides the information output. So, if the load is eliminated, means must be devised to sense mass movement. This is feasible with a properly designed modulation scheme, which in itself produces negligible mechanical reaction noise. A modulator is generally understood to be a device by which a low-frequency signal modifies a high-frequency carrier. The modulated carrier can then be amplified as desired, and a demodulator can recover the amplified low-frequency component. In this manner one avoids so-called 'one-over-*f*' noise, a characteristic noise injected by all active devices that control dc power (that is, amplifiers) and which increases dramatically at periods greater than 10 s. Figure 31 of part 2, in the section on carrier amplifiers, illustrates this with factual data.

Application of the above principles eventually made possible the development in 1970 of a more useful 'downhole' seismometer—the Geotech Model 36000 seismometer—known locally as the 'K-S Seismometer,' after its designers Burnard Kirkpatrick and O. D. Starkey. This seismometer can be lowered inside a 7-inch (outside diameter) 20 lb/ft API casing. The uncased mechanical assembly appears in Figure 24. In order, from the bottom upward, are shown the two horizontal components, the vertical component, and the air pulse mechanism. An air pulse is fed to a ball-and-socket joint at the top of each component case to free the joint momentarily and allow the case to seek a vertical position. This is necessary because, in general, the hole is not vertical. Figure 25 shows a cased assembly, including electronic components, ready to go down a hole. These seismometers were put in service in 1975 as the Seismic Research Observatory (SRO) seismograph system, described by *Peterson and Orsini* [1976], *Peterson et al.* [1976].

Fig. 24. Mechanical assembly of the 'force balance' K-S seismometers, Geotech Model 36000, later known as the SRO seismograph system.

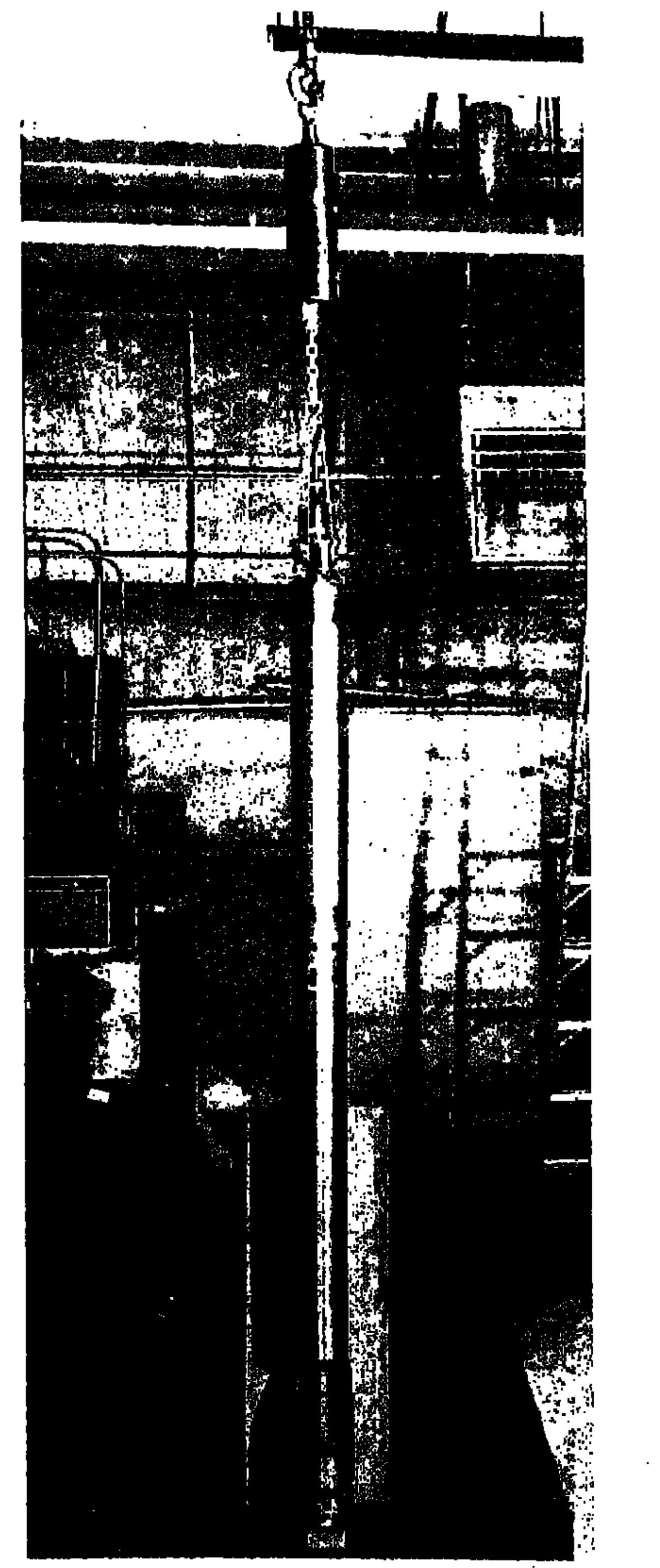

Fig. 25. Cased assembly of the Model 36000 seismometer, including downhole electronic components, ready to be lowered into a cased hole.

Bibliography

Atanasoff, J. V., and E. R. Kolsrud, Low-frequency vibration detection device, *U. S. Patent 2,739,297*, 1956.
Benioff, H., A new vertical seismograph, *Bull. Seismol. Soc. Am., 22*, 155–169, 1932.

Benioff, H., A reluctance seismograph for ultra long period waves, paper presented at Assemblée de Toronto, Assoc. de Seismol. et de Phys. de L'Interieur de la Terre, Sept. 1957.
Benioff, H. and F. Press, New results from long period seismographs, paper presented at Assemblée de Toronto, Assoc. de Seismol. et de Phys. de L'Interieur de la Terre, Sept. 1957.
Block, B., and R. D. Moore, Measurements in the earth mode frequency range by an electrostatic sensing and feedback gravimeter, *J. Geophys. Res.*, *71*, (18) 4361–4375, 1966.
Block, B., and R. D. Moore, Tidal to seismic frequency investigations with a quartz accelerometer of new geometry, *J. Geophys. Res.*, *75* (18), 1493–1505, 1970.
Byrne, C. J., Instrument noise in seismometers, *Bull. Seismol. Soc. Am.*, *51*, 69–84, 1961.
Dewey, J., and P. Byerly, The early history of seismometry (to 1900), *Bull. Seismol. Soc. Am.*, *59* (1), 183–227, 1969.
Ewing, M., and F. Press, Further study of atmospheric pressure fluctuations recorded on seismographs, *Eos Trans. AGU*, *34*, 95–100, 1953.
Fix, J. E., Ambient earth motion in the period range from 0.1 to 2560 sec., *Bull. Seismol. Soc. Am.*, *62*, 1753–1760, 1972.
Galitzin, B., Zur methodik der seismometrischen beobachtungen, *Izv. Akad. Nauk. SSSR*, *5* (19), 30–31, 1903. (Libr. Cong. Call No. AS262, S34.)
Gol'perin, E. I., *Polyarizatsionnyi Metod Seismicheskikh Issledovanii (Polarization Method of Seismic Prospecting)*, Nedra Press, Moskow, 1977.
Hamilton, J. H., and E. Stephens, Jr., New developments in seismological instrumentation, *Tech. Rep. 62-1*, 36 pp., The Geotech. Corp., Garland, Tex. 1962.
Haubrich, R. A., and G. S. MacKenzie, Earth noise, 5 to 500 millicycles per second, *J. Geophys. Res.*, *70* (6), 1429–1440, 1965.
La Coste, L. J. B., and A. Romberg, Force measuring device, *U. S. Patent 2,293,437*, 1942.
McCombie, C. W., Fluctuation theory in physical measurements, *Rep. Progr. Phys.*, *16*, 266–320, 1953.
Melton, B. S., and P. R. Karr, Polarity coincidence scheme for revealing signal coherence, *Geophysics 22*, 553–564, 1957.
Melton, Ben S., The La Coste suspension—principles and practice, *Geophys. J. R. Astron. Soc.*, *22*, 521–543, 1971.
Melton, B. S., The sensitivity and dynamic range of inertial seismographs, *Rev. Geophys. Space Phys.*, *14*, 93–116, 1976.
Melton, B. S., and D. P. Johnson, Inertial seismograph design—Limitations in principle and practice, *Proc. Inst. Radio. Eng.*, *50*, 2328–2339, 1962.
Melton, B. S., and B. M. Kirkpatrick, The symmetrical triaxial seismometer—its design for application to long-period seismometry, *Bull. Seismol. Soc. Am.*, *60*, 717–739, 1970.
Milatz, J. M. W., and J. J. van Zolingen, The Brownian motion of electrometers, *Physica*, *19*, 181–194, 1953.
Milatz, J. M. W., J. J. van Zolingen, and B. B. van Iperen, The reduction of Brownian motion of electrometers, *Physica*, *19*, 197–207, 1953.
Murphy, A. J., J. Savino, J. M. W. Rynn, G. L. Choy, and K. McCamy, Observations of long-period (10-100 sec) seismic noise at several worldwide locations, *J. Geophys. Res.*, *77* (26), 5042–5049, 1972.
Peterson, J., and N. A. Orsini, Seismic Research Observatories: Upgrading the worldwide seismic data network, *Eos Trans. AGU*, *57*, 548–556, 1976.
Peterson, J., H. M. Butler, L. G. Holcomb, and C. R. Hutt, The Seismic Research Observatory, *Bull. Seismol. Soc. Am.*, *66*, 2049–2068, 1976.
Savino, J., K. McCamy, and G. Hade, Structures in earth noise beyond twenty seconds, A window for earthquakes, *Bull. Seismol. Soc. Am.*, *62*, 141–176, 1972.
Trott, W., Investigation of noise in long-period seismographs, *Tech. Rep. 65-91*, Teledyne Geotech, Garland, Texas, 1965.
Weinstein, W. D., Flexure pivot bearings, *Mach. Des.*, *37*, 150–157, June 10, and 136–145, July 8, 1965.
Wenner, F., A new seismometer equipped for electromagnetic damping and electromagnetic and optical magnification, *J. Res. Nat. Bur. Stand. (U.S.)*, *2*, 963–999, 1929.
Wolf, A., The limiting sensitivity of seismic detectors, *Geophysics*, *7*, 115–122, 1942.

Ben S. Melton, from Dallas, Texas, received the B.S. degree in electrical engineering from Rice University, Houston, in 1925.

Following a student engineering course at the General Electric Company and a short time as engineer with the Gulf States Utilities Company, Port Arthur and Beaumont, Texas, he was employed by the General Exploration Company, Houston, to do research and development work in electromagnetic prospecting for oil, during the years 1928 to 1930. Late in 1930 he entered the field of seismograph prospecting with Geophysical Service, Inc., Dallas, and except for a short period, remained in that work until 1942, becoming associated with the National Geophysical Company, Dallas, from 1937 until April 1942. That year he joined the staff of the Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland, as a radio engineer on the proximity-fuse project. Later he was involved in development of optical and other methods for examining supersonic flow in connection with ramjet flight.

In December 1948 he accepted appointment as a geophysicist with the U.S. Air Force, in connection with the program to detect and identify underground nuclear explosions. Upon retirement from this Air Force program in 1965, he became an independent consultant.

Melton is a charter member of the Society of Exploration Geophysicists, a senior member of the Institute of Electrical and Electronic Engineers, and a member of the American Geophysical Union and the Seismological Society of America. He is a registered professional engineer in the state of Texas.

News

NSF Losing Earth Sciences Research Funds

The Earth Sciences Division (EAR) of the National Science Foundation (NSF) faces a diminishing financial base from which to award grants for research, while the proposal pressure increases. Robin Brett, director of the division stated, 'Now that the Ocean Drilling Division has become a separate entity [within the Foundation] the Division of Earth Sciences has no major facility, and with the exception of COCORP, at $2.8 million per year, we are a small science division, consisting of four programs—geology, geophysics, geochemistry, and petrology.'

Brett noted, however, that the field of earth sciences research, which the NSF attempts to support, has grown rapidly in the past decade. 'Growth (in terms of people employed in the field) is predicted to increase markedly, as the following quotation from Science and Engineering Education for the 1980s and Beyond (NSF publication, 1980) attests:

"Among the sciences, growth (between 1978 and 1990) is put at 40% for psychologists, *geologists*, statisticians, and economists. Occupations with projected slow growth include atmospheric scientists, physicists and astronomers, and mathematicians, all of which are projected at 10 percent or less."

'The average grant has decreased in dollar value rapidly

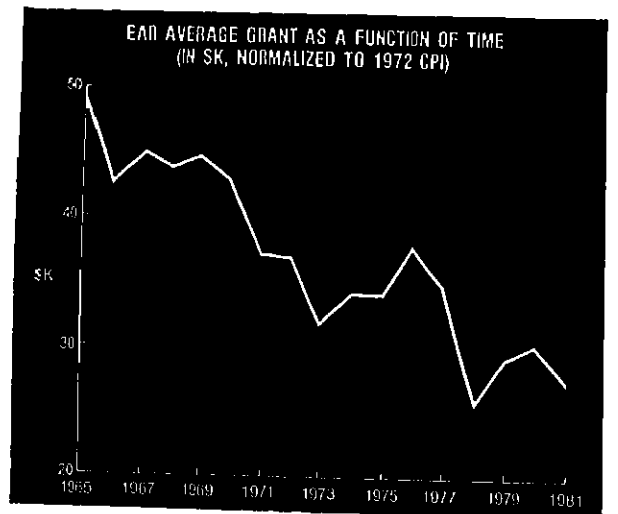

Fig. 1. Plot of the average annual grant made by the Earth Sciences Division (EAR) of the National Science Foundation as a function of time (in $K normalized to 1972 CPI).

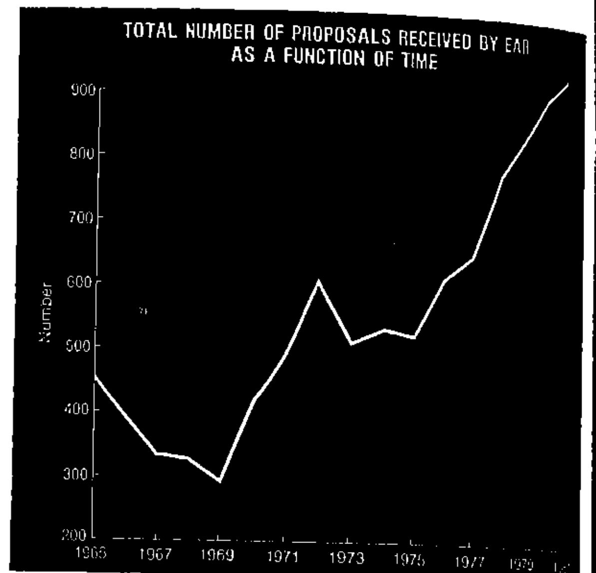

Fig. 2. Total number of proposals received by the Earth Sciences Division (EAR) of the National Science Foundation as a function of time.

during the past decade or so, Brett said. In 1965 the average grant was close to $50,000.00 in the earth sciences. (See Figure 1.) In 1981 the average annual grant is about $27,000.00. Inflation has caused the decrease, while the ratio of the budgeted dollar per investigator has remained less than level, and while the cost of research has increased; instrumentation is not cheap: one modern mass spectrometer laboratory costs $400,000.00, enough to equip ten earth science departments thirty years ago!'

At the same time, the portions of grants allocated to be spent on investigator's salaries and institutional overhead have increased.

A major problem at the NSF Earth Sciences Division today is the enormous number of research proposals. It is an almost impossible task to process the proposals, much less fund them. The NSF visitor today will see 10–15-ft stacks of proposals being moved about, warehouse style, by forklift trucks. A current joke at the NSF is that assistant program managers are being hired just to enable the divisions to hire secretaries to handle the load of proposals. Congress has repeatedly cut the staff and operation of NSF, but the work load continues to increase. The number of proposals received by the NSF Earth Sciences Division is increasing by an exponential function (see Figure 2).—*PBT*

HEAO-2 Completes Flight Mission

The second High-Energy Astronomy Observatory (HEAO 2) has expended its control gas supply, completing its flight mission.

The spacecraft was launched Nov. 13, 1978. It carried the world's largest focusing X ray telescope and an array of imaging and analyzing astronomy instruments. During its extra-long lifetime, it performed thousands of studies of X-ray-emitting stars, supernova remnants, galaxies, and quasars.

HEAO 2 is one of a family of three highly successful scientific satellites managed by NASA's Marshall Space Flight Center, Huntsville, Ala. With 2 years and 5 months of operations, HEAO 2, like its predecessor HEAO 1, performed more than twice as long as its design called for—a feat expected to be equaled by the third observatory, which is still in operation.

Although it will take years for participating astronomers to analyze completely all the data they received, important data have already been obtained about the X ray output of normal stars, the composition of supernova remnants, the distribution of mass in galaxies and clusters of galaxies, and the origin of the extragalactic X ray background.

The spacecraft was operating extremely well, Marshall Center officials reported, when it expended the last of its reaction control gas Saturday afternoon, April 25, and could no longer maintain its pointing attitude. Spacecraft and instrument engineering tests were performed until the batteries were discharged, and on a subsequent orbit Sunday morning, when the solar panels were receiving sunlight, all systems were powered down. Reentry and burnup are expected to take place next year.—*PMB* [Source: NASA]

Petroleum Research Grants

Five earth sciences grants are available through the American Chemical Society's Petroleum Research Fund (PRF). These grants are intended to assist 'advanced scientific education and fundamental research in the "petroleum field," which may include any field of pure science which . . . may afford a basis for subsequent research directly connected with the petroleum field,' according to Justin W. Collat, PRF program administrator.

The grants are divided into three categories, Collat said. The first, called type AC, generally supports graduate students or postdoctoral fellows. Awards may be up to $15,000 per year for a maximum of 3 years. The second, type B, is for faculty research with undergraduate students in academic departments which do not offer a Ph.D. degree. The maximum award is $6500 annually for 2 years. And last, a special 'starter' grant program is available for beginning faculty investigators. These grants consist of $10,000 for 2 years, Collat said, and are limited to faculty members in the first 3 years of their first faculty appointment. These faculty members cannot have any major support of their research, except for that provided by their institution.

Proposals, accepted throughout the year, are evaluated by the 24-member PRF Advisory Board.

For additional information, contact Collat, The Petroleum Research Fund, American Chemical Society, 1155 16th Street, N.W., Washington, D.C. 20036 (telephone: 202-872-4481).—*BTR*

Geophysical Event

Pagan Volcano, Mariana Islands, Western Pacific Ocean (18.13°N, 145.80°E). All times are local (GMT + 10 h). A strong explosive eruption from North Pagan, the larger of the two stratovolcanoes that form the Pagan volcano complex, began on May 15. While reporting strong felt seismicity on the island, radio operator Pedro Castro suddenly announced at 0915 that the volcano was erupting. Communication was then cut off. An infrared image returned from the Japanese geostationary weather satellite at 1000 showed a very bright circular cloud about 80 km in diameter over the volcano. The cloud spread SE at about 70 km/h, and by 1600 its maximum height was estimated at 13.5 km from satellite imagery. Weakening of activity was evident on the image returned at 1900, and on the next image, at 2200, feeding of the eruption cloud had stopped, with the proximal end of the cloud located about 120 km SE of the volcano. No additional activity has been detected on the satellite images, but by 0400 the next morning, remnants of the plume had reached 10°N and 155°E.

Aircraft attempting to land on Pagan Island were prevented from doing so by the eruption. At 1235, pilots reported a mushroom cloud over the island and ashfall over its northern and eastern ends. Ash falls were also reported from Agrigan Island, 105 km to the NW. Additional pilot reports at 1410 indicated that the eruption was intensifying and that the cloud had reached more than 7-km altitude. United Press International reports that aircraft crews flying past the island at two different (but unspecified) times saw ash rising to 10.5 and 18 km. The U.S. Navy reported 'lava' flowing down the NE and NW flanks into the sea and about 2½ km down the SW flank to within 1 km of the island's village and 1/2 km of the airstrip. However, the aircraft instruments measured surface temperature of the 'lava' at 200° Fahrenheit.

The Japanese merchant ship *Hoyo Maru* rescued all 53 persons on Pagan Island early May 16. None of the residents were injured.

The U.S. Geological Survey sent a three-man team from the Hawaiian Volcano Observatory to Pagan Island but they had not reached it by the time of this report.

Information contacts: Frank Smigielski, NOAA/National Environmental Satellite Service, Synoptic Analysis Branch, S/OP33, Camp Springs, Maryland 20233.
Gus Telegadas, Room 617, NOAA/Air Resources Laboratory, Silver Spring, Maryland 20910.
Robert Tilling, U.S. Geological Survey, Stop 906, National Center, Reston, Virginia 22092.
U.S. Department of Defense.
United Press International.

Geophysicists

Daniel P. Beard was appointed executive director of the Renewable Natural Resources Foundation, effective May 1. He succeeds *Gordon Fredine*, who has retired.

Farouk El-Baz, of the Smithsonian's National Air and Space Museum, was presented with the Arab Republic of Egypt 'Order of Merit-First Class' by President Anwar Sadat. El-Baz, cited for his contributions to space geology, advises Sadat on scientific matters. The presentation was made at the First Science Celebration Day in Cairo, on April 14.

James F. Hays will succeed *Raymond Siever* as chairman of the Department of Geological Sciences at Harvard University as of July 1. Siever will remain on the department's faculty.

Peter J. Schreuder has been appointed a vice president at Geraghty & Miller, Inc., consulting groundwater geologists and hydrologists. He is the director of the company's Tampa, Fla., and Baton Rouge, La., offices.

Kenneth M. Watson was appointed director of the Marine Physical Laboratory at Scripps Institution of Oceanography. He comes to Scripps after serving for more than 20 years as a professor of physics and researcher at the University of California at Berkeley and at the Lawrence Berkeley Laboratory. Watson succeeds *Fred N. Spiess*, who now heads the University of California's Institute of Marine Resources. (Photo courtesy of Scripps)

Geophysicist Obituaries

The following AGU members are recently deceased:
Joseph M. Caldwell, 69, on December 21, 1980. Joined in 1942.
William M. Chapple, 46, on February 18, 1981. Joined in 1964.
James E. Gill, 80, in January, 1981. Life member, joined in 1947.
James Gilluly, 84, on December 31, 1980. Life Fellow, joined in 1934.
Nathan M. Newmark, 70, on January 25, 1981. Fellow, joined in 1962.
Anthony J. Polos, 71, in June, 1980. Life member, joined in 1942.
Ernest Tillotson, 77, on March 29, 1981. Life member, joined in 1947.
George D. Whitmore, 82, on February 9, 1981. Life member, joined in 1946.

New Publications

Early Diagenesis, A Theoretical Approach

R. A. Berner, *Princeton Ser. in Geochem.*, Princeton University Press, Princeton, New York, xii + 241 pp., 1980, $25 (cloth), $9.50 (paper).

Reviewed by Donald L. Graf

In the last 15 years the author has carried out field and laboratory studies of solid importance to an impressive variety of areas in sedimentary geochemistry. This activity, coupled with his lively curiosity about established theoretical concepts in other sciences that can be brought to bear on geochemical problems, has yielded numerous scientific articles and an earlier book, in 1971. We encounter most of the theoretical aspects of these publications again here, leavened with additional calculations, more recent literature citations, and additional insights about applicability obtained during the intervening years of teaching and research.

The transport equations that form the theoretical core of the book should be familiar to chemical engineers, hydrologists, petroleum reservoir engineers, and physical oceanographers. Most of the applications are to ocean sediments. The book is divided into a theoretical section, in which suitable equations are developed to describe the physical, biological, and chemical processes encountered in diagenesis, and a discussion of applications to marine sediments of the continental margins, deep-sea sediments, and nonmarine sediments. However, because much of the literature cited in the latter section involves tests of mathematical models, the book is in practice an interplay throughout between equations and sets of data, with interspersed excerpts from peripheral fields (e.g., equilibrium thermodynamics, ion exchange, rate laws, microbial reactions, nucleation, and crystal growth).

Even though some useful mathematical simplifications result from considering only the first few hundred meters of sediment, the problems considered are still very complex. The common-sense approach used by Berner and his fellow modelmakers is first to define theoretical relationships with reasonable but not ultimate precision, then to seek plausible ways of simplifying these expressions for particular problems, next to accumulate a number of tests of the simplified expressions against particular sets of data, and then to fine-tune back and forth until models are obtained that, we hope, are uniquely successful in describing a particular geochemical environment.

The book is a veritable encyclopedia of simplifying assumptions (11 are cited in developing one model for calcium carbonate distribution on the floor of the deep ocean), which raises problems in comparing results from different workers with slightly different notions of optimum simplification. The facility with which physical units are redefined is a little unsettling, e.g., because bioturbation is sometimes lumped within the diffusion term in modeling, it emerges (p. 31) as a category of diffusion. Dispersion is another category (p. 31), which should interest hydrologists, who have made molecular diffusion into chemical dispersion.

A blessing of complex natural systems is that they afford safety valves for models that do not quite fit—aragonite dissolving in the middle of your calcite-dissolution study area, ions poisoning the surface of your mineral so that it doesn't follow an ideal rate law in dissolving (certainly a demonstrated effect in some systems). One could, finally, list some misleading statements in the highly condensed summaries about peripheral scientific areas.

However, none of these concerns does serious damage to the central business of modelmaking. Recent efforts that have been able to use several different kinds of measurements are particularly impressive, e.g., Aller's lateral-diffusion model for predicting ammonia distribution in the bioturbated zone and Emerson and Widmer's treatment of vivianite precipitation in Lake Greifensee sediments. The contributions of stable- and radioactive-isotopic measurements are underrepresented.

This is a sprightly tour through the library and computer room of a country manor where the air is filled with the music of Ravel and with jests about sedimentologists and whales. Take the tour by all means, and come back again after the new wings are built.

Donald L. Graf is a member of the Department of Geology of the University of Illinois at Urbana-Champaign.

Light Scattering by Irregularly Shaped Particles

D. W. Schuerman (Ed.), Plenum, New York, x + 334 pp., 1980, $39.50.

Reviewed by E. Raschke

This book contains the text of two introductory papers and extended abstracts of 35 contributed papers which were presented during the International Workshop on Light Scattering by Irregularly Shaped Particles (June 5–7, 1979, State University of New York at Albany, New York). The purpose of this workshop was to review the state of understanding and the modeling of the scattering of electromagnetic radiation by irregularly shaped particles and to compare it with the first-order solutions which usually are based on equivalent spherical particles.

The field of application is extremely wide. It reaches from interpretations of stellar atmospheres, interplanetary dusts, and atmospheric aerosols to the observation of plankton and other suspended materials in the oceans with remote sensing methods.

The papers of this workshop did not cover all subjects. In the introduction, D. Deirmendjian, a meteorologist, favored the empirical approach (i.e., in situ measurements and adjustments to equivalent particles). J. Majo Greenberg, however, recommended extensive basic research of the physical processes involved in scattering of light by irregularly shaped particles; thus, the particle shape must be known and remote sensing techniques should use all means to exploit the information content carried by the scattered light.

The other 35 papers have been gathered into 6 subgroups:

1. User needs: In four papers are discussed the remote sensing of ice clouds, lidar visibility measurements, and several applications. Here, no contribution has been made from oceanography and astronomy.
2. Particle descriptions: Five papers describe exhaustively the shape of raindrops and ice crystals, and of aerosols from various regions. Here, again, the subject should have been extended to the other fields of applications, oceanography, and astronomy.
3. Theoretical methods: Fourteen papers discuss various ways to compute the scattering by particles of various shapes. All contributions cover the subject in great depth, allowing the reader to gain an overview.
4. Experimental methods: Ten papers were presented during this session. In several of them, microwave analog experiments are described, where the extinction of single 'analog' particles is directly measured. The methodology of in situ measurements (i.e., measurements of the extinction properties of a 'volume of air') has not changed, but the technology has improved considerably. Almost all authors recommended without detailed discussion that measurements be made of as many components of the scattering matrix as possible. This chapter alone deals with the scattering by biological particles.
5. Inversion and information content: Only two papers were devoted to this subject, since even for simpler problems of scattering by pure spherical particles it is yet relatively unexplored. In one paper the size of the scatterer is inferred from polarization measurements, an attractive tool which is seldom used. In the other paper a comparison is made between irregularly shaped and spherical particles, using laser and direct solar radiation measurements. The conclusion is that nonspherical particles in the atmosphere may be considered as equivalent spheres without serious error.

Although many abstracts are rather short and contain only limited information, this book can be considered as an extremely helpful tool for all those research groups and individuals who are engaged in remote sensing of particle properties and quantities, either when the particles are imbedded in another medium (gases or water) or entirely free in deep space. I recommend open publications of such proceedings, because it allows the worldwide community to participate in discussions of extreme importance to their research. Expected future restrictions on travel funds will even force such means of scientific communications. A paperback version would seem adequate and less expensive than this book.

The organizers of this meeting should be encouraged to attempt another one, but it should include a much wider field of scientific research and broader international participation than they could assemble at this workshop.

E. Raschke is with the Institute for Geophysik and Meteorolog, University of Cologne, Köln, West Germany.

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Research Seismologist/Solid Earth Geophysics. ENSCO, Inc. in Springfield, Virginia is seeking a Program Manager/Research Seismologist to support an expanding program in solid earth geophysics. Research areas will include: seismic network data processing associated with the detection, identification and location of natural and man-made seismic sources; earthquake characterization and source mechanism studies; explosion source characterization; and empirical studies using near field and far field seismic data. Experience in theoretical and observational seismology at regional and teleseismic distances, is highly desirable. Experience in digital time series analysis is desirable. Ph.D. in seismology is highly desirable, however, M.S. level with experience in earthquake and explosion seismology will be considered. Salary and benefits are extremely competitive. Resumes along with salary requirements should be submitted to the Personnel Department at the address below, Attention Code SAS. ENSCO, Inc., 5400-A Port Royal Road, Springfield, VA 22151.
Equal employment opportunity/AAP.

Sedimentologist or Sedimentary Petrologist/University of California, Santa Barbara. Applications are invited for a tenure track appointment in soft rock geology to be filled in 1981–82. Rank dependent on qualifications and experience but preference will be given to the assistant professor level. Applicant should normally have a Ph.D. and strong field-orientation and quantitative background. The candidate will be expected to develop a strong research program in clastic sedimentation as related to basin analyses. The candidate will also be expected to teach at both undergraduate and graduate levels and interact with students and faculty of the department, particularly in the general areas of clastic diagenesis, volcanic processes, paleomagnetics, as well as field geology. Additional duties may include teaching physical geology and summer field geology.
Please send resume, other documentation of abilities, and four letters of recommendation by August 31, 1981 to Dr. Arthur G. Sylvester, Chairman, Department of Geological Sciences, University of California, Santa Barbara, CA 93106. Telephone (805) 961-3156.
The University of California is an affirmative action/equal opportunity employer.

Postdoctoral/Research Associate Positions, The Johns Hopkins University, Applied Physics Laboratory. Positions are available for studies of magnetospheric-ionospheric coupling, hydromagnetic waves, and plasma instabilities in the ionosphere and magnetosphere. The selected candidates will participate in the analysis and interpretation of data from spacecraft and ground-based radars as well as in the development and implementation of new ground-based and spacecraft studies. Positions are for one year and are renewable. Tenure may begin at any time through September 1, 1981. Applications should be addressed to Mr. Steven F. Sayre, Dept. ADI-15, The Johns Hopkins University, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.
An equal opportunity employer, m/f.

Physical Oceanographer. The Pacific OCS Office, Bureau of Land Management, is seeking qualified candidates for a staff oceanographer to supervise contracted marine environmental research. The primary areas of research will be physical oceanography and meteorology. Duties include serving as a contracting officer's authorized representative, developing study plans and research statements and advising management on matters within the candidate's area of expertise. Grade level: GS 9/11/12, salary $18,585– [illegible] Send a current SF 171 by June 6, 1981 to Administrative Officer, Bureau of Land Management, [illegible] 300, Los Angeles, CA 90017 [illegible] call 213-688-7120.

Mineralogy and Petrology. Applications are invited for a faculty position at Weber State College, effective September 1981. This is a permanent faculty position with rank, salary, and tenure track status determined by qualifications. Responsibilities include teaching undergraduate courses in mineralogy, petrology, and geochemistry or some combination of mineral deposits, structural geology and introductory geology. Ph.D. preferred. WSC is a large (10,000 students) undergraduate college with a strong geology program graduating about 10–15 majors per year. The college is situated in northern Utah at the boundary between the Rocky Mountain and Great Basin Provinces and adjacent to the Overthrust Belt. The Department is well equipped for field-oriented teaching and research. The closing date for applications is July 1, 1981. Applications, including evidence of teaching proficiency and the names of three references should be sent to S. R. Ash, Chairman, Department of Geology/Geography, Weber State College, 3750 Harrison Blvd., Ogden, Utah 84408.
An equal opportunity/affirmative action employer, M/F.

Research Seismologist. The Alexandria Laboratories of Teledyne Geotech invites applications from Ph.D.-level seismologists to work on problems related to the comprehensive and threshold test ban treaty negotiations. Applicants should have background in such topics as theoretical seismology, seismic data analysis, seismic data gathering, advanced scientific computing, and computer systems. To apply please send your resume to Jean Hill, Pesonnel Department, Teledyne Geotech, 314 Montgomery Street, Alexandria, Virginia 22314.
An equal opportunity employer.

Visiting Lecturer in Geophysics. Geology Department seeks one year visiting lecturer 1981–82 to teach exploration geophysics and assist with operation of earthquake laboratory (includes WWSSN Station). Require Ph.D. or nearly completed Ph.D. Apply to the Geology Department, University of Montana, Missoula, MT 59812. Deadline August 1, 1981. Telephone (406) 243-2341.
EEO/AA employer.

Arizona State University, Department of Chemistry. Visiting professor, 1982–83 academic year or part thereof. We seek a person or persons with established research programs in geochemistry, mineralogy, petrology, and/or solid state chemistry to teach advanced special topics course(s), interact with faculty and students, and pursue own research. May be an excellent sabbatical opportunity for established scientist. Contact A. Navrotsky, Department of Chemistry, Arizona State University, Tempe, AZ 85281 [illegible]
An AA/EO employer.

Research Position in Chemical Oceanography. California Institute of Technology, Division of Geological and Planetary Sciences. The position of research fellow is being offered at Caltech for research in oceanography. Investigation of the isotopic composition of neodymium and rare earth abundances in sea water and sediments is now being carried forward. The mechanism of injection of REE into sea water will be studied. The differences in $^{143}Nd/^{144}Nd$ in various water masses [Piepgras et al., Earth and Planet. Sci. Lett. 45, 223–236 (1979); Piepgras and Wasserburg, Earth and Planet. Sci. Lett. 50, 128–138 (1980)] is now being carried forward as an exploratory venture in order to determine the origin and chemical behavior of REE in the ocean and the potential use of $^{143}Nd/^{144}Nd$ as a tracer. The laboratory facilities for sample preparation and analysis are fully functional and will be available. Applicants should have training in oceanography and a good perspective on general [illegible] oceanographic models. [illegible] resume and references to Professor [illegible] Wasserburg, Lunatic Asylum, California Institute of Technology, Pasadena, CA 91125. [illegible] an equal opportunity/affirmative action employer (M/F/H). [illegible]

Physical Oceanographer: Memorial University of Newfoundland. Memorial University of Newfoundland in St. John's seeks to fill two faculty positions in physical oceanography. One position is in ocean dynamics and the other is in theoretical oceanography. Interest and experience in carrying out field programs is desirable. Candidates for both positions should hold a Ph.D. in physical oceanography, or a closely related field (e.g. fluid mechanics).
The program in physical oceanography at Memorial University is new and offers the successful applicant an opportunity to participate in the development of this field in a frontier area. Memorial University is located in St. John's, Newfoundland, which is rapidly becoming a centre of ocean studies related to fisheries and offshore hydrocarbon development in Eastern Canada.
Salary will be commensurate with experience and qualifications.
Applications, including curriculum vitae and the names of three referees, are to be submitted to:
Dr. C. W. Cho
Head
Department of Physics
Memorial University of Newfoundland
St. John's, Newfoundland
A1B 3X7

Faculty Position/University of Alaska, Fairbanks. Applications are invited for a tenure track faculty position in economic geology in the Geology-Geophysics Program to teach undergraduate and graduate courses in ore deposits, mineralogy, and exploration geology.
Applications should have demonstrated practical experience in mineral exploration, regional and detailed geologic mapping as well as a commitment to research in the genesis of ore deposits. The candidate will be expected to pursue a vigorous graduate teaching and research program in economic geology with students primarily oriented toward careers in the mineral industry.
Preference will be given to individuals with experience in arctic or subarctic minerals research and a record of close collaboration with the mineral industry. Academic rank and salary commensurate with experience. Ph.D. required.
Send resume and three letters of reference Director, Division of Geosciences, University of Alaska, Fairbanks, Alaska 99701. Applications will be accepted until June 30, 1981, or until filled.
The University of Alaska is an equal opportunity/affirmative action employer.

Sedimentologist-Sedimentary Petrographer/Ohio State University. The department of Geology and Mineralogy invites applications for a tenure track faculty position in sedimentology-sedimentary petrography. The appointment is available from August 1981.
Salary and rank competitive and commensurate with experience.
Applicants should send resumes and names of at least three referees or address inquiries for further information to Peter-N. Webb, Dept. of Geology and Mineralogy, The Ohio State University, 125 South Oval Mall, Columbus, Ohio 43210. Closing date is July 1, 1981.
The Ohio State University is an equal opportunity/affirmative action employer.

Seismology. Research associate position anticipated (September 1, 1981), telemetry monitoring project in Virginia. Problems focus on seismicity and neotectonics in the state. Prefer M S geophysicist with thesis in observational seismology, but others considered. Applications, transcripts and two letters of recommendation to: Dr. G. A. Bollinger, Seismological Observatory, VPI&SU, Blacksburg, Virginia 24061. Deadline for receipt of applications is August 1, 1981.
VPI&SU is an equal opportunity/affirmative action employer.

Research Fellow/Sedimentary Geochemistry. The Australian National University invites applications for appointment as research fellow in sedimentary geochemistry, Research School of Earth Sciences. The School has a well equipped trace element laboratory, including an MS7 Spark Source Mass Spectrometer, with access to electron microprobe and XRD facilities.
The successful applicant should hold a Ph.D. degree and have a good background in geology, geochemistry, analytical chemistry, sedimentology and Pre Cambrian geology and should have experience in the use of the above analytical techniques.
He or she will be expected to participate in joint research projects dealing with the use of trace element geochemistry in elucidating the composition and evolution of the Earth's crust through studies of sedimentary rock sequences.
In addition, applicants are invited to submit research proposals detailing the general research directions and specific projects which they would wish to pursue. Further information concerning the position can be obtained directly from Dr. S. R. Taylor.
Applicants should submit a detailed curriculum vitae, a publications list and the names and addresses of three referees.
Appointment as research fellow will be up to three years in the first instance with the possibility of extension to five years. Salary range: $A19132 to $A24972 per annum ($A1 = $US1.14). Superannuation, housing assistance, reasonable appointment costs.
The University reserves the right not to make an appointment or to make an appointment by invitation at any time.
Applications should be sent to The Registrar, The Australian National University, PO Box 4, CANBERRA, ACT 2600, AUSTRALIA by 3 AUGUST 1981.

Biogeochemist or Organic Geochemist. Research assistant professor with interest in organic matter cycling in coastal sediment systems, as part of interdisciplinary group. Academic year appointment with opportunity for renewal. Resume, names of three references, and letter of research interests by July 1 to L. Mayer, Ira C. Darling Center, University of Maine at Orono, Walpole, Maine 04573.
Equal opportunity/affirmative action employer.

Crustal Seismology: Princeton University. Candidates with an interest in any of the following are invited to apply for research staff appointments:
1. Marine seismic data analysis and structure of oceans and ocean margins.
2. Narrow and wide angle reflection seismology applied to continental crustal geology.
3. Wave propagation theory and techniques of seismic data analysis.

Princeton University has an ongoing program for the creative reanalysis of existing multichannel reflection data—such as COCORP and USGS offshore data. Special projects are undertaken from time to time to collect field data in critical areas or to test new methods of data collection and analysis. A high performance 32 bit minicomputer system for data analysis and theoretical work is to be installed later this year.
Applicants should send curriculum vitae and a list of three references to:
Robert A. Phinney
Department of Geological and Geophysical Sciences
Princeton University
Princeton, NJ 08544
Or inquire: 609-452-4118.
Date of appointment and salary are negotiable.
Princeton University is an equal opportunity employer.

AGU

New Member Sponsors

One hundred sixty-six members were elected between March 31 and April 30, 1981. The AGU members who sponsored them are listed below. Earlier lists were published March 24 and April 28.

Three Members: Robert B. Smith. **Two Members:** M. S. T. Bukowinski, David S. Chapman, Robert A. Duncan, Bryan L. Isacks, Charles M. Keefer, LaVerne D. Kulm, James S. McClain, Forrest Mozer, W. J. Raitt, Thomas C. Royer, and Donald U. Wise.

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liam B. Rossow, Peter H. Roth, Jacob Rubin, David Rusch, Sidney L. Russak.
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Meetings

Applied Glaciology Symposium

The International Glaciology Society has slated its second meeting on the applied aspects of snow and ice research for August 23–27, 1982, at the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. This Second Symposium on Applied Glaciology will include technical sessions on the engineering problems of floating ice; engineering problems of ground ice; icebergs and glaciers; properties and behavior of snow and ice; snow removal and control; avalanche control and snow pressure; ice accretion; and modeling techniques in applied glaciology.

For additional information, contact the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom.

Coastal Engineering Conference

The 18th International Conference on Coastal Engineering will be held November 14–19, 1982, in Cape Town, Republic of South Africa.

Topics to be covered at the conference include wind current and wave action; tides and long waves; sedimentary processes and coastal morphology; estuary and inlet behavior; coastal structures and recreational facilities; ship motions and harbor entrance design; ocean outfall design and construction; and environmental aspects of coastal engineering.

Five copies of a synopsis (not to exceed two pages) of papers proposed for the conference should be sent to Billy L. Edge, Secretary, Coastal Engineering Research Council, Department of Civil Engineering, Clemson University, Clemson, SC 29631. Deadline is October 31, 1981.

Underwater Mining Institute

The 12th Underwater Mining Institute is scheduled for October 20–22 in Madison, Wisconsin. The program will include presentations on mineralogy of marine sulfide deposits; tectonic setting for spreading center sulfide deposits; seafloor sulfides in the Galapagos and other Pacific areas; new developments in southeast Asia offshore tin operations; geophysical techniques for finding underwater copper lodes; new geochemical techniques for marine minerals exploration; changes in the international mining trade of relevance to marine mining; and the impact of sea grant minerals research on industry. The program will also include tours to local research laboratories.

For registration information, contact Gregory Hedden, Sea Grant Advisory Services, University of Wisconsin, 1815 University Avenue, Madison, WI 53706 (telephone: 608/262-0644).

For technical program information, contact J. Robert Moore, Marine Science Institute, University of Texas, P.O. Box 7999, University Station, Austin, TX 78712 (telephone: 512/471-4816).

AGU Midwest Meeting

September 17–18
Minneapolis, Minnesota

Abstract Deadline: July 1
Convenor: V. Rama Murthy

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Mantle structure and dynamics. Contact Geoffrey Davies or Clem Chase.
Rock water interactions: Hydrothermal processes and metallogenesis. Contact William Seyfried.
Precambrian crustal evolution of the North American continent. Contact Paul Weiblen.
Geomagnetism and paleomagnetism. Contact Subir Banerjee.
Hydrology in the mid-continental U.S. Contact H. O. Pfannkuch or E. C. Alexander, Jr.

Abstracts

Use standard AGU format (see page 20 of January 13 *Eos*) and send original and two copies of abstracts to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, with a substantive meeting report after the meeting. There will be no abstract charge.

Aquifer Protection Policies

A special program entitled 'Effects of New Aquifer Protection Regulations and Policies on Ground Water Management' will be held at the American Society of Civil Engineers' Spring Convention and Exhibit during the week of April 19, 1982, in Las Vegas, Nevada. The program is sponsored by the Hydraulic Division's Committee on Ground Water Hydrology and by the Environmental Engineering Division's Committee on Hazardous Waste Management.

A call for papers has been issued for the following topics: review of regulatory activity, future protection regulations, and policies; groundwater quality monitoring; design of well networks; groundwater studies stemming from regulations, including remedial measures; and ongoing and needed research. Research topics should address pollution sources, transport and fate of pollutants, methods of detection, and aquifer rehabilitation.

Geophysicists interested in presenting a paper should send a one-page abstract to Richard J. Schicht, Illinois State Water Survey, 605 East Springfield Avenue, P.O. Box 5050, Station A, Champaign, IL 61820 (telephone: 217/333-2594). Deadline is July 31.

Workshop on Remote Measurement of Underwater Parameters

This workshop was held at Bolkesjo, Norway, October 30 to November 1, 1980. It was arranged by the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division; Institute of Geophysical Research, University of Bergen; and Office of Naval Research, Arlington, Virginia. It was sponsored by the Royal Norwegian Council for Scientific and Industrial Research, the North Atlantic Treaty Organization, and the Office of Naval Research.

One may conclude from the meeting that the idea that it may be possible to determine any subsurface variables of the ocean by remote sensing is attractive in principle, but realizable now, in a severely limited manner, and still possible of advancement. Sound waves are now used for tracking SOFAR floats to map out deep and mid-level currents, and acoustic tomography offers possibilities that are now being explored in the field, with the first tentative results now being reported. Acoustic tomography measures a combination of velocity and sound speed fields over the water column, and the data can be interpreted to give mean variables and a number of integral measures of water properties as well as statistical measures of the field of variables. The upper mixed layer is not so well sampled by acoustic tomography, so for the upper layer, one will have to rely upon other methods. In saltwater, electromagnetic waves cannot be used profitably; for brackish or fresh water overlying salt water, radar monopulse methods offer some promise. Such methods are in routine use for ice profiling on lakes and rivers, and extension to estuaries may prove useful and practical.

Satellite interrogation of drifters, and shore station tracking of drifting buoys are other methods of obtaining information about the ocean without having to go there each time one wants information.

Among the active methods of sensing variables in the upper ocean are ground wave and ionospheric scatter radar. The ground wave radar method, one example of which is CODAR, when used from shore, can sense the current field in the upper 1/2 meter of the ocean with a special resolution of 1.5 km² and 0.10 m/s. While a few examples were given of synthetic aperture radar (SAR) signatures in SEASAT-SAR data, the processing algorithm was not described in sufficient detail to enable one to make any judgement about the method, although in principle it should be possible to infer current along one direction from Doppler-shifted reflections. The SAR data also show a strong correlation between bathymetry and sea surface roughness. As at previous workshops where these data have been presented, there was little, if any, analysis given of the dynamics of the processes. The active optical methods, using laser light sources, take advantage of the following effects: the Rayleigh scattering broadens the spectral width, and the broadening is temperature dependent. Thus, one may be able to measure temperature by observing the reflected light from pulsed, range-gated lasers.

Next comes Raman backscatter for measurements of salinity, temperature, and other variables, and then comes Brillouin scattering to sense sound velocity. When a very intense laser signal hits the water, it will also heat it and generate an acoustic signal. The reflection of the acoustic signal back to the surface (by density structures) will in turn generate a measurable surface signature. One can use this for depth sounding from airplanes and, ultimately, from even more remote platforms. The combination of possibilities, although few of them are now at a stage ready for routine practical use, suggests that one should follow developments closely. The methods, so far, seem to be mainly useful in the upper 50 m of the ocean but may some day be extended to several times that depth. This will tell us very little about the deeper water column. But the possibility of obtaining synoptic data, even in the upper few meters, seems interesting. The technology needs to be worked out, and the oceanographic community need not yet hold its collective breath and sit around and wait, but the new methods may be upon us in a few years. The active and passive remote sensing of water properties has, of course, also been extended to sensing of biological properties. Here the workshop contained a very interesting set of papers on algorithms and the inverse problem and an example of application of color measurement to mud flat and tidal flat properties.

The first paper was by N. K. Hojerslev, who showed that different regions of the ocean have sufficiently different plankton-related color that a universal algorithm for interpreting color in terms of biological measures will have serious shortcomings. The next paper, by J. Fischer and H. Grassl, who had examined the problem of remote sensing of particulates, found that the problem of determining particulate matter variables from color observations was not well conditioned and that the matrix really had only two linearly independent characteristic vectors. The tentative conclusion of this listener to these two papers was that before one can use color to determine biological variables, one needs to introduce some information about local biological properties as a constraint on the inversion process. This means that one needs biologists to help with the interpretation; one cannot find a way where the technology system and the computer can do it all by themselves. This should not be a source of wonder because biology is a nontrivial branch of science and cannot be left to automation. One has to develop a certain judgement and expertise before one can produce useful results.

The Coastal Zone Color Scanner provides useful information for biologists, but the information from the intensity of color bands cannot be used blindly, it has to be interpreted through the use of knowledge about local biology as a constraint on the inversion process. An example of how to incorporate local knowledge in an inversion problem was given by Prober, Bahr, and Dennert-Muller, who interpreted the LANDSAT images from different channels, in terms of tidal flat classes, including dry sand, wet mud, and others, by using 'training fields' and in situ establishment of field characteristics. The use of these training fields introduced the local constraint on the inversion process and made it possible to classify a large region from LANDSAT data after field work in a limited area that covered the important classes of flats.

This is apparently the direction in which one has to seek methods for interpreting upper ocean color. Also, no doubt, the same method can be used with active sensors, where one senses the color quality of reflection of laser lights from different depths, including fluorescence effects.

While some of the methods seemed kind of far from practical realization in the near future, there is rapid technology development under way.

The workshop was informative for the participants, and the sober assessments provided by the working groups showed that one cannot dismiss remote sensing techniques out of hand, that the technologists need to encounter scientists to learn what one should look for, and it showed how one may adjoin specialist knowledge to remote sensing data. In that sense the workshop was educational, realistic, and productive of sober evaluations of methods. An abstract volume will be available shortly from the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division, P.O. Box 309, Blindern, Gaustadallen 30 D, Oslo, 3, Norway.

This meeting report was prepared and submitted by Erik Mollo-Christensen of the Department of Meteorology and Physical Oceanography at MIT, Cambridge.

Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

May 27–29 Canadian Meteorological and Oceanographic Society 15th Annual Congress, Saskatoon, Saskatchewan, Canada. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 1–4 First JECSS Workshop Tokyo, Japan. Sponsor, Tsukuba University. (Takashi Ichiye, Dept. of Oceanography, Texas A&M University, College Station, TX 77843.)

June 1–5 **Second International Symposium on Inertial Technology for Surveying and Geodesy,** Banff, Canada. Sponsors, AGU, Canadian Institute of Surveying, Univ. of Calgary. (Klaus-Peter Schwarz, ISS Symposium 1981, Division of Surveying Engineering, Univ. of Calgary, Calgary, Alberta T2N 1N4 Canada.)

June 3–4 Symposium on the Ecology and Management of Reservoirs, Université Laval, Quebec, Canada. Sponsors, Unesco, Université du Quebec, Université Laval, Hydro-Quebec, Société d'Energie de la Baie James. (P. G. C. Campbell, Université Quebec, INRS-Eau, C.P. 7500, Ste. Foy, Quebec G1V 4C7 Canada.)

June 4–5 Eastern Snow Conference, Syracuse, N.Y. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 7–11 **Eighth Ocean Energy Conference for the Department of Energy,** Washington, D.C. Sponsor, Marine Technology Society. (Harry Irwin, Marine Technology Society, 1730 M St., N.W., Washington, DC 20036.)

June 8–10 **International Geoscience and Remote Sensing Symposium,** Washington D.C. Sponsors, AGU, IEEE Geoscience and Remote Sensing Society. (F. T. Ulaby, Remote Sensing Laboratory, Univ. of Kansas Center for Research, Inc., West Campus, Lawrence, KS 66045.)

June 14–19 Second International Conference on Urban Storm Drainage, Urbana, Ill. Sponsors, Univ. of Illinois, International Liaison in Urban Storm Drainage, International Association of Hydraulic Research, International Association of Water Pollution Research, American Society of Civil Engineers. (B. C. Yen, Department of Civil Engineering, Univ. of Illinois, Urbana, IL 61801.)

June 15–19 International IEEE/APS Symposium, National Radio Science Meeting, and International IEEE/MTT Symposium, Los Angeles, Calif. (Prof. N. G. Alexopoulos, 7732 Boelter Hall, Department of Electrical Sciences, Univ. of California, Los Angeles, CA 90024.)

June 22–26 International Symposium on Erosion and Sediment Transport Measurement, Florence, Italy. Sponsors, IAHS, International Commission on Continental Erosion, National Research Council of Italy. (P. Tacconi, Secretary of the Organizing Committee, Istituo di Ingegneria Civile Via S. Marta, 3 50139 Firenze, Italy.)

June 23–26 Seventh International Symposium on the Machine Processing of Remotely-Sensed Data, West Lafayette, Ind. Sponsor, Laboratory for Applications of Remote Sensing, Purdue Univ. (D. B. Morrison, Purdue Univ./LARS, 1220 Potter Dr., West Lafayette, IN 47906.)

June 24–26 International Symposium on Real-Time Operation of Hydrosystems, Waterloo, Ontario, Canada. Sponsor, Water Resources Group, Univ. of Waterloo. (T. E. Unny or E. A. McBean, Univ. of Waterloo, Department of Civil Engineering, Waterloo, Ontario N2L 3G1 Canada.)

June 29–July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology. (Barbara Dullea, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.)

June 29–July 3 Conference/Workshop on Heterogeneous Catalysis—Its Importance to Atmospheric Chemistry, Albany, N.Y. Sponsors, NSF, NASA. (V. A. Mohnen, Atmospheric Sciences Research Center, State Univ. of New York, Albany, NY 12222.)

June 29–July 11 Seminar on Fluid-Dynamical Problems in Astrophysics and Geophysics, Chicago, Ill. Sponsors, American Mathematical Society, Society for Industrial and Applied Mathematics. (Meeting Arrangements Department, American Mathematical Society, Post Office Box 6248, Providence, R.I.)

July 6–11 Geocongress '81-South African Geodynamics Project and 3rd International Platinum Symposium, Pretoria, South Africa. Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat S. 217, CSIR, P.O. Box 395, Pretoria 0001 Republic of South Africa.)

July 8–10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsor, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 15–17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Buchanan, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21–23 **Chapman Conference on Spatial Variability in Hydrologic Modeling,** Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

July 21–30 21st General Assembly of IASPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27–30 **Eighth International Symposium on Urban Hydrology, Hydraulics, and Sediment Control,** Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 206B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug. 3–15 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug. 4–7 International Conference on Energy Education, Providence, R.I. (Donald Kirwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9–15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, ICCL, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 9–18 International Congress of Surveyors, F.I.G., Montreux, Switzerland. Sponsor, Fédération Internationale Des Geometres. (American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 10–14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10–14 Water Forum '81: Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage. (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22044.)

Aug. 10–19 20th General Assembly of the International Union of Radio Science, Washington, D.C. (R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418.)

Aug. 17–28 Third Scientific Assembly of IAMAP with Extraordinary General Assembly, Hamburg, Federal Republic of Germany. (S. Ruttenburg, NCAR, P.O. Box 3000, Boulder, CO 80307.)

Aug. 17–18 Open Symposium on Mathematical Models of Radio Propagation, Washington, D.C. Sponsor, URSI. (J. R. Wait, Bldg. 20, Electrical Engineering Department, Univ. of Arizona, Tucson, AZ 85721.)

Aug. 17–22 Ninth International Symposium on Earth Tides, New York, N.Y. Sponsors, IAG, IUGG, Columbia Univ. (J. T. Kuo, 828 S.W. Mudd, Columbia Univ., New York, NY 10027.)

Aug. 18–21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Haigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5061.)

Aug. 20–21 Second International Symposium on Computer-Aided Seismic Analysis and Discrimination, North Dartmouth, Mass. Sponsors, Electrical Engineering Department, Southeastern Massachusetts University, IEEE Computer Society, IEEE Acoustics, Speech and Signal Processing Society. (C. H. Chen, Electrical Engineering Department, Southeastern Massachusetts University, North Dartmouth, MA 02747.)

Aug. 24–26 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodaetisk Institut. (C. C. Tscherning, International Symposium Management of Geodetic Data, Geodaetisk Institut, Gamlehave Alle 22, Charlottenlund DK-2920 Denmark.)

Aug. 24–29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (C.-E. Lund, Chairman Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 556, 22 Uppsala, Sweden.)

Aug. 25–27 The Royal Institution of Chartered Surveyors Centenary Celebration, London, England. (Representative Radlinski, American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 28–Sept. 9 Arc Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan, IAVCEI. (Daisuke Shimozuru, IAVECEI Symposium on Arc Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31–Sept 2 Third International Colloquium on Mars, Pasadena, Calif. Sponsors, NASA, Lunar and Planetary Institute, Division of Planetary Sciences of the AAS. (Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109.)

Aug. 31–Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 Munchen 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairman of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c/o LNEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7–12 Third International Symposium on Antarctic Glaciology, Columbus, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society. (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 8–12 American Society of Photogrammetry-American Congress on Surveying and Mapping Fall Convention, San Francisco, Calif. (L. W. Aggers, USGS, 345 Middlefield Road, Mall Stop 31, Menlo Park, CA 94025.)

Sept. 13–17 National Water Well Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 16–18 **Oceans '81,** Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering, AGU. (R. Nagle, Publicity Manager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 17–18 **Midwest Meeting,** Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept. 17–18 **Pacific Northwest Regional Meeting,** Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 98920.)

Sept. 20–22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 28–Oct. 10 NATO Advanced Study Institute on Chemistry of the Unpolluted and Polluted Troposphere, Corfu, Greece. (W. Jaeschke, Center of Environmental Protection, University of Frankfurt, Robert-Mayer-Str. 11, 6000 Frankfurt/Main, FRG.)

Oct. 6–8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. El-Shaarawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 11–14 Coastal Society's Seventh Annual Conference, Galveston, Tex. (N. West, Coastal Society Conference, Department of Geography and Marine Affairs, Univ. of Rhode Island, Kingston, RI 02881.)

Oct. 11–15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 446, La Habra, CA 90631.)

Oct. 13–15 Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, La. Sponsors, Louisiana Geological Survey, Department of Natural Resources; Energy Programs Office, Louisiana State University; U.S. Department of Energy. (Ann Bachman, Conference Coordinator, Energy Programs Office, 105 Hill Memorial, Louisiana State Univ., Baton Rouge, LA 70803.)

Oct. 13–16 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hapke, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14–16 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 633 Sixth Ave., S.W., Calgary, Alberta, Canada T2P 2Y5.)

Oct. 22–24 Fourth Conference on the Physics of the Jovian and Saturnian Magnetospheres, Laurel, Md. Sponsor, NASA. (S. M. Krimigis, Applied Physics Laboratory, Johns Hopkins Univ., Laurel, MD 20810.)

Oct. 26–30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shorelines Commission of the International Union for Quaternary Research, Scientific Committee of the World Confederation of Underwater Activities. (Patricia M. Masters, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

November 1–5 Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oreg. Sponsor, Estuarine Research Federation. (Jay F. Watson, Treasurer, USFWS Suite 1962, 500 N.E. Multnomah Street, Portland, OR 92232.)

Nov. 2–6 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Ames Research Center, Moffott Field, CA 94035.)

Nov. 9–11 Special Conference on the Mechanical Behavior of Salt, University Park, Pa. Sponsor, Rock Mechanics Laboratory, Department of Mineral Engineering, Pennsylvania State University. (H. Reginald Hardy, Jr., Rock Mechanics Laboratory, Room 117, Mineral Sciences Building, Pennsylvania State University, University Park, PA 16802.)

Nov. 9–20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAG, IUGG Local Committee of Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography. (R. Omandi, Survey of Kenya, P.O Box 30046, Nairobi, Kenya.)

Nov. 30–Dec. 11 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM, Research Division, Box 218, Yorktown Heights, NY 10598; or G. S. Watson, Bernoulli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08544.)

Dec. 3–5 Topical Conference on the Processes of Planetary Rifting, San Francisco, Calif. Sponsor, Lunar and Planetary Institute. (Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Dec. 7–11 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 18–19 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluva, Istituto di Petrografia, Via Gramsci 9, 43100 Parma, Italy.)

Classified

EOS offers classified space for Positions Available, Positions Wanted, and Services, Supplies, Courses, and Announcements. There are no discounts or commissions on classified ads. Any type that is not publisher's choice is charged for at display rates. EOS is published weekly on Tuesday. Ads must be received in writing on Monday 1 week prior to the date of the issue required.

Replies to ads with box numbers should be addressed to Box ___, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

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POSITIONS AVAILABLE

Research Seismologist/Solid Earth Geophysics. ENSCO, Inc. in Springfield, Virginia is seeking a Program Manager/Research Seismologist to support an expanding program in solid earth geophysics. Research areas will include: seismic network data processing associated with the detection, identification and location of natural and man-made seismic sources; earthquake characterization and source mechanism studies; explosion source characterization; and empirical studies using near field and far field seismic data. Experience in theoretical and observational seismology at regional and teleseismic distances, is highly desirable. Experience in digital time series analysis is desirable. Ph.D. in seismology is highly desirable, however, M.S. level with experience in earthquake and explosion seismology will be considered. Salary and benefits are extremely competitive. Resumes along with salary requirements should be submitted to the Personnel Department at the address below. Attention Code SAS, ENSCO, Inc., 5400-A Port Royal Road, Springfield, VA 22151.

Equal employment opportunity/AAP.

Sedimentologist or Sedimentary Petrologist/University of California, Santa Barbara. Applications are invited for a tenure track appointment in soft rock geology to be filled in 1981–82. Rank dependent on qualifications and experience but preference will be given to the assistant professor level. Applicant should normally have a Ph.D. and strong field-orientation and quantitative background. The candidate will be expected to develop a strong research program in clastic sedimentation as related to basin analyses. The candidate will also be expected to teach at both undergraduate and graduate levels and interact with students and faculty of the department, particularly in the general areas of clastic diagenesis, volcanic processes, paleomagnetics, as well as field geology. Additional duties may include teaching physical geology and summer field geology.

Please send resume, other documentation of abilities, and four letters of recommendation by August 31, 1981 to Dr. Arthur G. Sylvester, Chairman, Department of Geological Sciences, University of California, Santa Barbara, CA 93106. Telephone (805) 961-3156.

The University of California is an affirmative action/equal opportunity employer.

Postdoctoral/Research Associate Positions, The Johns Hopkins University, Applied Physics Laboratory. Positions are available for studies of magnetospheric-ionospheric coupling, hydromagnetic waves, and plasma instabilities in the ionosphere and magnetosphere. The selected candidates will participate in the analysis and interpretation of data from spacecraft and ground-based radars as well as in the development and implementation of new ground-based and spacecraft studies. Positions are for one year and are renewable. Tenure may begin at any time through September 1, 1981. Applications should be addressed to Mr. Steven F. Sayre, Dept. ADI-15, The Johns Hopkins University, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20820.

An equal opportunity employer, m.f.

Physical Oceanographer. The Pacific OCS Office, Bureau of Land Management, is seeking qualified candidates for a staff oceanographer to supervise contracted marine environmental research. The primary areas of research will be physical oceanography and meteorology. Duties include serving as a contracting officer's authorized representative, developing study plans and work statements and advising management on matters within the candidate's area of expertise. Grade level: GS 9/11/12, salary $18,585–26,951. Send a current SF 171 by June 6, 1981 to Administrative Officer, Bureau of Land Management, 1340 W. Sixth St., Rm 200, Los Angeles, CA 90017. For more information, call 213-688-7120.

Mineralogy and Petrology. Applications are invited for a faculty position at Weber State College, effective September 1981. This is a permanent faculty position with rank, salary, and tenure track status determined by qualifications. Responsibilities include teaching undergraduate courses in mineralogy, petrology, and geochemistry and some combination of mineral deposits, structural geology and introductory geology. Ph.D. preferred. WSC is a large (10,000 students) undergraduate college with a strong geology program graduating about 10–15 majors per year. The college is situated in northern Utah at the boundary between the Rocky Mountain and Great Basin Provinces and adjacent to the Overthrust Belt. The Department is well equipped for field-oriented teaching and research. The closing date for applications is July 1, 1981. Applications, including evidence of teaching proficiency and the names of three references should be sent to S. R. Ash, Chairman, Department of Geology/Geography, Weber State College, 3750 Harrison Blvd., Ogden, Utah 84408.

An equal opportunity/affirmative action employer, M/F.

Research Seismologist. The Alexandria Laboratories of Teledyne Geotech invites applications from Ph.D.-level seismologists to work on problems related to the comprehensive and threshold test ban treaty negotiations. Applicants should have background in such topics as theoretical seismology, seismic data analysis, seismic data gathering, advanced scientific computing, and computer systems. To apply please send your resume to Jean Hill, Personnel Department, Teledyne Geotech, 314 Montgomery Street, Alexandria, Virginia 22314.

An equal opportunity employer.

Visiting Lecturer in Geophysics. Geology Department seeks one year visiting lecturer 1981–82 to teach exploration geophysics and assist with operation of earthquake laboratory (includes WWSSN Station). Require Ph.D. or nearly completed Ph.D. Apply to the Geology Department, University of Montana, Missoula, MT 59812. Deadline August 1, 1981. Telephone (406) 243-2341.

EEO/AA employer.

Arizona State University, Department of Chemistry. Visiting professor, 1982–83 academic year or part thereof. We seek a person or persons with established research programs in geochemistry, mineralogy, petrology, and/or solid state chemistry to teach advanced special topics course(s), interact with faculty and students, and pursue own research. May be an excellent sabbatical opportunity for established scientist. Contact: A. Navrotsky, Department of Chemistry, Arizona State University, Tempe, AZ 85281, (602) 965-4241.

An AA/EO employer.

Research Position in Chemical Oceanography. California Institute of Technology, Division of Geological and Planetary Sciences. The position of research fellow is being offered at Caltech for research in oceanography. Investigation of the isotopic composition of neodymium and rare earth abundances in sea water and sediments is now being carried forward. The mechanism of injection of REE into sea water will be studied. The differences in $^{143}Nd/^{144}Nd$ in various water masses (Piepgras et al., Earth and Planet. Sci. Lett., 45, 223–236 and Piepgras and Wasserburg, Earth and Planet. Sci. Lett. 50, 128–138 (1980)) is now being carried forward as an exploratory venture in order to determine the origin and chemical behavior of REE in the ocean and the potential use of $^{143}Nd/^{144}Nd$ as a tracer. The laboratory facilities for sample preparation and analysis are fully functional and will be available. Applicants should have training in oceanography and a good perspective on general physical oceanographic models.

Send resume and references to Professor G. J. Wasserburg, Lunatic Asylum, California Institute of Technology, Pasadena, CA 91125.

Caltech is an equal opportunity/affirmative action employer (M/F/H).

UNOLS Executive Secretary

The University-National Oceanographic Laboratory System (UNOLS) is soliciting applications for an Executive Secretary. UNOLS is an organization of academic institutions for the coordination and planning of oceanographic facilities, chiefly research vessels. The Executive Secretary administers the functions of UNOLS and heads the UNOLS Office which is located at and hosted by a Member laboratory. New office location is now pending. Institutions which have signified an intention to propose hosting the office are:

University of Delaware
The Johns Hopkins University, Chesapeake Bay Institute
Lamont-Doherty Geological Observatory of Columbia University
University of Southern California, Institute for Marine and Coastal Studies
University of Washington
Woods Hole Oceanographic Institution

It is anticipated that proposing institutions will negotiate with one or more applicants to become a part of their proposal, and selection will be based, in part, on the qualifications of the successful applicant who will become an employee of the host institution. Required qualifications include experience in oceanographic research and knowledge of research ship operations. Salary is negotiable depending on professional qualifications. Deadline for applications is July 31, 1981.

For further information, contact:

UNOLS Office
Box 54P
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(617) 548-1400, Ext. 2352

An equal opportunity employer M/F/H

Physical Oceanographer: Memorial University of Newfoundland. Memorial University of Newfoundland in St. John's seeks to fill two faculty positions in physical oceanography. One position is in ocean dynamics and the other is in theoretical oceanography. Interest and experience in carrying out field programs is desirable. Candidates for both positions should hold a Ph.D. in physical oceanography, or a closely related field (e.g. fluid mechanics).

The program in physical oceanography at Memorial University is new and offers the successful applicant an opportunity to participate in the development of this field in a frontier area. Memorial University is located in St. John's, Newfoundland, which is rapidly becoming a centre of ocean studies related to fisheries and offshore hydrocarbon development in Eastern Canada.

Salary will be commensurate with experience and qualifications.

Applications, including curriculum vitae and the names of three referees, are to be submitted to:

Dr. C. W. Cho
Head
Department of Physics
Memorial University of Newfoundland
St. John's, Newfoundland
A1B 3X7

Faculty Position/University of Alaska, Fairbanks. Applications are invited for a tenure track faculty position in economic geology in the Geology-Geophysics Program to teach undergraduate and graduate courses in ore deposits, mineralogy, and exploration geology.

Applications should have demonstrated practical experience in mineral exploration, regional and detailed geologic mapping as well as a commitment to research in the genesis of ore deposits. The candidate will be expected to pursue a vigorous graduate teaching and research program in economic geology with students primarily oriented toward careers in the mineral industry.

Preference will be given to individuals with experience in arctic or subarctic minerals research and a record of close collaboration with the mineral industry. Academic rank and salary commensurate with experience. Ph.D. required.

Send resume and three letters of reference Director, Division of Geosciences, University of Alaska, Fairbanks, Alaska 99701. Applications will be accepted until June 30, 1981, or until filled.

The University of Alaska is an equal opportunity/affirmative action employer.

Sedimentologist-Sedimentary Petrographer/Ohio State University. The department of Geology and Mineralogy invites applications for a tenure track faculty position in sedimentology-sedimentary petrography. The appointment is available from August 1981.

Salary and rank competitive and commensurate with experience.

Applicants should send resumes and names of at least three referees or address inquiries for further information to Peter-N. Webb, Dept. of Geology and Mineralogy, The Ohio State University, 125 South Oval Mall, Columbus, Ohio 43210. Closing date is July 1, 1981.

The Ohio State University is an equal opportunity/affirmative action employer.

Seismology. Research associate position anticipated (September 1, 1981), telemetry monitoring project in Virginia. Problems focus on seismicity and neotectonics in the state. Prefer M.S. geophysicist with thesis in observational seismology, but others considered. Applications, transcripts and two letters of recommendation to: Dr. G. A. Bollinger, Seismological Observatory, VPI&SU, Blacksburg, Virginia 24061. Deadline for receipt of applications is August 1, 1981.

VPI&SU is an equal opportunity/affirmative action employer.

Research Fellow/Sedimentary Geochemistry. The Australian National University invites applications for appointment as research fellow in sedimentary geochemistry, Research School of Earth Sciences. The School has a well equipped trace element laboratory, including an MS7 Spark Source Mass Spectrometer, with access to electron microprobe and XRD facilities.

The successful applicant should hold a Ph.D. degree and have a good background in geology, geochemistry, analytical chemistry, sedimentology and Pre Cambrian geology and should have experience in the use of the above analytical techniques.

He or she will be expected to participate in joint research projects dealing with the use of trace element geochemistry in elucidating the composition and evolution of the Earth's crust through studies of sedimentary rock sequences.

In addition, applicants are invited to submit research proposals detailing the general research directions and specific projects which they would wish to pursue. Further information concerning the position can be obtained directly from Dr. S. R. Taylor.

Applicants should submit a detailed curriculum vitae, a publications list and the names and addresses of three referees.

Appointment as research fellow will be up to three years in the first instance with the possibility of extension to five years. Salary range: $A19132 to $A24972 per annum ($A1 = $US1.14). Superannuation, housing assistance, reasonable appointment costs.

The University reserves the right not to make an appointment or to make an appointment by invitation at any time.

Applications should be sent to The Registrar, The Australian National University, PO Box 4, CANBERRA, ACT 2600, AUSTRALIA by 3 AUGUST 1981.

Biogeochemist or Organic Geochemist. Research assistant professor with interest in organic matter cycling in coastal sediment systems, as part of interdisciplinary group. Academic year appointment with opportunity for renewal. Resume, names of three references, and letter of research interests by July 1 to L. Mayer, Ira C. Darling Center, University of Maine at Orono, Walpole, Maine 04573.

Equal opportunity/affirmative action employer.

Crustal Seismology: Princeton University. Candidates with an interest in any of the following are invited to apply for research staff appointments:

1. Marine seismic data analysis and structure of oceans and ocean margins.
2. Narrow and wide angle reflection seismology applied to continental crustal geology.
3. Wave propagation theory and techniques of seismic data analysis.

Princeton University has an ongoing program for the creative reanalysis of existing multichannel reflection data—such as COCORP and USGS offshore data. Special projects are undertaken from time to time to collect field data in critical areas or to test new methods of data collection and analysis. A high performance 32 bit minicomputer system for data analysis and theoretical work is to be installed later this year.

Applicants should send curriculum vitae and a list of three references to:

Robert A. Phinney
Department of Geological and Geophysical Sciences
Princeton University
Princeton, NJ 08544

Or inquire: 609-452-4118
Date of appointment and salary are negotiable.

Princeton University is an equal opportunity employer.

Consejo Nacional de Investigaciones Cientificas y Técnicas

CHIEF OCEANOGRAPHER

A postdoctoral scientist with several years experience in physical oceanography is required at IADO (Instituto Argentino de Oceanografia), a joint Institution of the Consejo Nacional de Investigaciones Cientificas Y Técnicas (National Research Council), the Universidad del Sur, Bahia Blanca, and the Armada Argentina (Argentine Navy).

The applicant, in addition to research and postgraduate teaching in his own field, will also be responsible for the planning, coordination, and supervision of activities in other branches of oceanography at large.

The position is under the auspices of a joint program of the Consejo Nacional de Investigaciones Cientificas y Técnicas (CONICET) and the Interamerican Development Bank (IDB). It will be initially of medium duration, and is renewable.

It will be located at Bahia Blanca. Salary and fringe benefits according to qualification. Knowledge of Spanish language will be considered an advantage. For consultations or submitting applications, contact:

Señor Presidente del
Consejo Nacional de Investigaciones
Cientificas y Técnicas
Avda. Rivadavia 1917
(1033) Buenos Aires, Argentina.

Applications should include complete academic and professional background along with a list of publications as well as names and addresses of three references.

AGU

New Member Sponsors

One hundred sixty-six members were elected between March 31 and April 30, 1981. The AGU members who sponsored them are listed below. Earlier lists were published March 24 and April 28.

Three Members: Robert B. Smith. **Two Members:** M. S. T. Bukowinski, David S. Chapman, Robert A. Duncan, Bryan L. Isacks, Charles M. Keefer, LaVerne D. Kulm, James S. McClain, Forrest Mozer, W. J. Raitt, Thomas C. Royer, and Donald U. Wise.

One Member: Thomas J. Ahrens, Walter Alvarez, Don L. Anderson, James G. Anderson, Kinsey A. Anderson, Moha Ashour-Abdalla, Steven Bachman, George E. Backus, Fred Baker, Steven C. Bergman, Dale Bibee, Sveinbjorn Bjomsson, Ross A. Black, D. L. Blackstone, Jr., Gunnar Bodvarsson, Frances M. Boler, Martin H. P. Bott, E. Boyle, L. W. Braile, Randolph W. Bromery, Charles A. Brott, Robert C. Brown, R. L. Bruhn, Roger G. Burns.

Robert S. Carmichael, Mingteh Chang, Charles R. Chappell, R. J. Clegg, John W. Clough, Ron M. Clowes, Charles E. Corbato, Charles S. Cox, Richard G. Craig, Kenneth M. Creer, Geoffrey F. Davies, Paul M. Davis, Howard W. Day, Paul S. DeCarli, Robert E. Dennis, Steven R. Dickman, F. A. Donath, H. James Dorman, Leroy M. Dorman, Charles L. Drake, Richard E. DuBroff, Fred Duennebier.

Dieter H. Ehhalt, David S. Evans, Hans P. Evgster, Leonard S. Fedor, Michael Fehler, Robert W. Ferguson, Henry F. Fliegel, L. Neil Frazer, F. A. Frey, A. Shelby Frisch, T. J. Fitzgerald, Joseph Frizado, Cliff Frohlich, Kazuya Fujita, Michael O. Garcia, Ronald J. Gibbs, Freeman Gilbert, R. W. Girdler, Billy Price Glass, Ambrose Golcoechea, Melvyn L. Goldstein, Paul Greleman.

Frank Hadsell, Gregory D. Harper, C. G. A. Harrison, Halstead Harrison, Larry A. Haskin, Gary E. Hauser, Craig O. Hayenga, John G. Heacock, Hugh C. Heard, Robert A. Helliwell, Thomas L. Henyey, W. J. Hinze, Kenneth J. Hollett, Thomas E. Holzer, Jose Honnorez, Lonnie L. Hood, Robert Houtz, Robert L. Huguenin, Ru J. Hung, Anthony Irving, E. Irving, H. M. Iyer, Ansel G. Johnson, T. H. Jordan, JoAnn Joselyn.

Douglas L. Kane, M. Allan Keys, Charles D. Keeling, George H. Keller, W. Kertz, Raz Khaleel, Carl Kisslinger, Peter K. Kitanidis, Jan Kouba, Led Kristjansson, Arthur F. Kuckes, Andre S. Kusubov, Helmut E. Landsberg, Bjorn T. Larsen, Edwin E. Larson, B. E. Leake, Darrell I. Leap, Conway B. Leovy, Joel S. Levine, J. G. Liou, Austin Long, Daniel P. Loucks, Allen Lowrie, William J. Ludwig, Alan M. Lumb, Timothy M. Lutz.

William D. MacDonald, R. M. MacQueen, Thomas Maddock, James Magill, David C. Major, Stephen D. Malone, Murli H. Manghnani, Robert Mark, Bruce D. Marsh, David L. Martin, Russell McDuff, Michael B. McElroy, L. D. McGinnis, Stuart McHugh, Randolph Moberly, Walter Mooney, O. B. Moore, Dennis Wilson Moore, H. J. Morel-Seytoux, Helmut Moritz, L. J. Patrick Muffler, Patricia E. Murtha, Frederick Nagle, Manuel Nathenson, Richard S. Naylor, David L. Nebert, Anthony Nekut, F. M. Neubauer, Shlomo P. Neuman, R. W. Nicholls, Henry Joseph Neibauer, Richard W. Nightingale, Hallan C. Noltimier, Amos Nur.

W. P. Olson, Richard E. Orville, Benjamin M. Page, Donald F. Palmer, Chung Park, Robert L. Parker, David F. Paskausky, Bryan Pearce, Henry Perkins, K. A. Pfitzer, John A. Philpotts, Morris B. Pongratz, Raymond A. Price, Ivar B. Ramberg, Joseph B. Reagan, Charles R. Real, David L. Reasoner, Irwin Remson, Eugene D. Richard, John D. Richardson, Randall M. Richardson, Robert E. Riecker, Peter A. Rigotti, Peter Rogers, William M. Roggenthen, Wil-

liam B. Rossow, Peter H. Roth, Jacob Rubin, David Rusch, Sidney L. Russak.
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Pradeep Talwani, Michael A. Temerin, Ta-liang Teng, H. R. Thierstein, Ronald J. Thomas, T. R. Toppozada, Donald L. Turcotte, Petr Vanicek, Kenneth L. Verosub, Thomas A. Vogel, Elstratios G. Vomvoris, Carl A. Von Hake, William B. Wadsworth, Harve S. Waff, Mary Emma Wagner, Clyde Wahrhaftig, Raymond J. Walker, C. Wang, Steve Wegener, Ray F. Weiss, J. E. White, John M. Wilcox, James G. Williams, John Wilson, W. P. Winn, I. J. Won, David D. Wooldridge, Francis T. Wu, Shi Tsan Wu, Klaus Wyrtki, Gour-Tsyh Yeh, Hsueh-Wen C. Yeh.

Meetings

Applied Glaciology Symposium

The International Glaciology Society has slated its second meeting on the applied aspects of snow and ice research for August 23–27, 1982, at the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. This Second Symposium on Applied Glaciology will include technical sessions on the engineering problems of floating ice; engineering problems of ground ice; icebergs and glaciers; properties and behavior of snow and ice; snow removal and control; avalanche control and snow pressure; ice accretion; and modeling techniques in applied glaciology.

For additional information, contact the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom.

Coastal Engineering Conference

The 18th International Conference on Coastal Engineering will be held November 14–19, 1982, in Cape Town, Republic of South Africa.

Topics to be covered at the conference include wind current and wave action; tides and long waves; sedimentary processes and coastal morphology; estuary and inlet behavior; coastal structures and recreational facilities; ship motions and harbor entrance design; ocean outfall design and construction; and environmental aspects of coastal engineering.

Five copies of a synopsis (not to exceed two pages) of papers proposed for the conference should be sent to Billy L. Edge, Secretary, Coastal Engineering Research Council, Department of Civil Engineering, Clemson University, Clemson, SC 29631. Deadline is October 31, 1981.

Underwater Mining Institute

The 12th Underwater Mining Institute is scheduled for October 20–22 in Madison, Wisconsin. The program will include presentations on mineralogy of marine sulfide deposits; tectonic setting for spreading center sulfide deposits; seafloor sulfides in the Galapagos and other Pacific areas; new developments in southeast Asia offshore tin operations; geophysical techniques for finding underwater copper lodes; new geochemical techniques for marine minerals exploration; changes in the international mining trade of relevance to marine mining; and the impact of sea grant minerals research on industry. The program will also include tours to local research laboratories.

For registration information, contact Gregory Hedden, Sea Grant Advisory Services, University of Wisconsin, 1815 University Avenue, Madison, WI 53706 (telephone: 608/262-0644).

For technical program information, contact J. Robert Moore, Marine Science Institute, University of Texas, P.O. Box 7999, University Station, Austin, TX 78712 (telephone: 512/471-4816).

AGU Midwest Meeting

September 17–18
Minneapolis, Minnesota

Abstract Deadline: July 1
Convenor: V. Rama Murthy

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Mantle structure and dynamics. Contact Geoffrey Davies or Clem Chase.
Rock water interactions: Hydrothermal processes and metallogenesis. Contact William Seyfried.
Precambrian crustal evolution of the North American continent. Contact Paul Weiblen.
Geomagnetism and paleomagnetism. Contact Subir Banerjee.
Hydrology in the mid-continental U.S. Contact H. O. Pfannkuch or E. C. Alexander, Jr.

Abstracts

Use standard AGU format (see page 20 of January 13 *Eos*) and send original and two copies of abstracts to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, with a substantive meeting report after the meeting. There will be no abstract charge.

Aquifer Protection Policies

A special program entitled 'Effects of New Aquifer Protection Regulations and Policies on Ground Water Management' will be held at the American Society of Civil Engineers' Spring Convention and Exhibit during the week of April 19, 1982, in Las Vegas, Nevada. The program is sponsored by the Hydraulic Division's Committee on Ground Water Hydrology and by the Environmental Engineering Division's Committee on Hazardous Waste Management.

A call for papers has been issued for the following topics: review of regulatory activity, future protection regulations, and policies; groundwater quality monitoring; design of well networks; groundwater studies stemming from regulations, including remedial measures; and ongoing and needed research. Research topics should address pollution sources, transport and fate of pollutants, methods of detection, and aquifer rehabilitation.

Geophysicists interested in presenting a paper should send a one-page abstract to Richard J. Schicht, Illinois State Water Survey, 605 East Springfield Avenue, P.O. Box 5050, Station A, Champaign, IL 61820 (telephone: 217/333-2594). Deadline is July 31.

Workshop on Remote Measurement of Underwater Parameters

This workshop was held at Bolkesjø, Norway, October 30 to November 1, 1980. It was arranged by the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division; Institute of Geophysical Research, University of Bergen; and Office of Naval Research, Arlington, Virginia. It was sponsored by the Royal Norwegian Council for Scientific and Industrial Research, the North Atlantic Treaty Organization, and the Office of Naval Research.

One may conclude from the meeting that the idea that it may be possible to determine any subsurface variables of the ocean by remote sensing is attractive in principle, but realizable now, in a severely limited manner, and still possible of advancement. Sound waves are now used for tracking SOFAR floats to map out deep and mid-level currents, and acoustic tomography offers possibilities that are now being explored in the field, with the first tentative results now being reported. Acoustic tomography measures a combination of velocity and sound speed fields over the water column, and the data can be interpreted to give mean variables and a number of integral measures of water properties as well as statistical measures of the field of variables. The upper mixed layer is not so well sampled by acoustic tomography, so for the upper layer, one will have to rely upon other methods. In saltwater, electromagnetic waves cannot be used profitably; for brackish or fresh water overlying salt water, radar monopulse methods offer some promise. Such methods are in routine use for ice profiling on lakes and rivers, and extension to estuaries may prove useful and practical.

Satellite interrogation of drifters, and shore station tracking of drifting buoys are other methods of obtaining information about the ocean without having to go there each time one wants information.

Among the active methods of sensing variables in the upper ocean are ground wave and ionospheric scatter radar. The ground wave radar method, one example of which is CODAR, when used from shore, can sense the current field in the upper 1/2 meter of the ocean with a spacial resolution of 1.5 km^2 and 0.10 m/s. While a few examples were given of synthetic aperture radar (SAR) signatures in SEASAT-SAR data, the processing algorithm was not described in sufficient detail to enable one to make any judgement about the method, although in principle it should be possible to infer current along one direction from Doppler-shifted reflections. The SAR data also show a strong correlation between bathymetry and sea surface roughness. As at previous workshops where these data have been presented, there was little, if any, analysis given of the dynamics of the processes. The active optical methods, using laser light sources, take advantage of the following effects: the Rayleigh scattering broadens the spectral width, and the broadening is temperature dependent. Thus, one may be able to measure temperature by observing the reflected light from pulsed, range-gated lasers.

Next comes Raman backscatter for measurements of salinity, temperature, and other variables, and then comes Brillouin scattering to sense sound velocity. When a very intense laser signal hits the water, it will also heat it and generate an acoustic signal. The reflection of the acoustic signal back to the surface (by density structures) will in turn generate a measurable surface signature. One can use this for depth sounding from airplanes and, ultimately, from even more remote platforms. The combination of possibilities, although few of them are now at a stage ready for routine practical use, suggests that one should follow developments closely. The methods, so far, seem to be mainly useful in the upper 50 m of the ocean but may some day be extended to several times that depth. This will tell us very little about the deeper water column. But the possibility of obtaining synoptic data, even in the upper few meters, seems interesting. The technology needs to be worked out, and the oceanographic community need not yet hold its collective breath and sit around and wait, but the new methods may be upon us in a few years. The active and passive remote sensing of water properties has, of course, also been extended to sensing of biological properties. Here the workshop contained a very interesting set of papers on algorithms and the inverse problem and an example of application of color measurement to mud flat and tidal flat properties.

The first paper was by N. K. Højerslev, who showed that different regions of the ocean have sufficiently different plankton-related color that a universal algorithm for interpreting color in terms of biological measures will have serious shortcomings. The next paper, by J. Fischer and H. Grassl, who had examined the problem of remote sensing of particulates, found that the problem of determining particulate matter variables from color observations was not well conditioned and that the matrix really had only two independent characteristic vectors. The tentative conclusion of this listener to these two papers was that before one can use color to determine biological variables, one needs to introduce some information about local biological properties as a constraint on the inversion process. This means that one needs biologists to help with the interpretation; one cannot find a way where the technology system and the computer can do it all by themselves. This should not be a source of wonder because biology is a nontrivial branch of science and cannot be left to automation. One has to develop a certain judgement and expertise before one can produce useful results.

The Coastal Zone Color Scanner provides useful information for biologists, but the information from the intensity of color bands cannot be used blindly, it has to be interpreted through the use of knowledge about local biology as a constraint on the inversion process. An example of how to incorporate local knowledge in an inversion problem was given by Prober, Bahr, and Dennert-Muller, who interpreted the LANDSAT images from different channels, in terms of tidal flat classes, including dry sand, wet mud, and others by using 'training fields' and in situ establishment of field characteristics. The use of these training fields introduced the local constraint on the inversion process and made it possible to classify a large region from LANDSAT data after field work in a limited area that covered the important classes of flats.

This is apparently the direction in which one has to seek methods for interpreting upper ocean color. Also, no doubt, the same method can be used with active sensors, where one senses the color quality of reflection of laser lights from different depths, including fluorescence effects.

While some of the methods seemed kind of far from practical realization in the near future, there is rapid technology development under way.

The workshop was informative for the participants, and the sober assessments provided by the working groups showed that one cannot dismiss remote sensing techniques out of hand, that the technologists need to encounter scientists to learn what one should look for, and it showed how one may adjoin specialist knowledge to remote sensing data. In that sense the workshop was educational, realistic, and productive of sober evaluations of methods. An abstract volume will be available shortly from the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division, P.O. Box 309, Blindern, Gaustadallen 30 D, Oslo, 3, Norway.

This meeting report was prepared and submitted by Erik Mollo-Christensen of the Department of Meteorology and Physical Oceanography at MIT, Cambridge.

Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

May 27–29 Canadian Meteorological and Oceanographic Society 15th Annual Congress, Saskatoon, Saskatchewan, Canada. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 1–4 First JECSS Workshop Tokyo, Japan. Sponsor, Tsukuba University. (Takashi Ichiye, Dept. of Oceanography, Texas A&M University, College Station, TX 77843.)

June 1–5 **Second International Symposium on Inertial Technology for Surveying and Geodesy,** Banff, Canada. Sponsors, AGU, Canadian Institute of Surveying, Univ. of Calgary. (Klaus-Peter Schwarz, ISS Symposium 1981, Division of Surveying Engineering, Univ. of Calgary, Calgary, Alberta T2N 1N4 Canada.)

June 3–4 Symposium on the Ecology and Management of Reservoirs, Université Laval, Quebec, Canada. Sponsors, Unesco, Université du Quebec, Université Laval, Hydro-Quebec, Societé d'Energie de la Baie James. (P. G. C. Campbell, Université Quebec, INRS-Eau, C.P. 7500, Ste. Foy, Quebec G1V 4C7 Canada.)

June 4–5 Eastern Snow Conference, Syracuse, N.Y. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 7–11 **Eighth Ocean Energy Conference for the Department of Energy,** Washington, D.C. Sponsor, Marine Technology Society. (Harry Irwin, Marine Technology Society, 1730 M St., N.W., Washington, DC 20036.)

June 8–10 **International Geoscience and Remote Sensing Symposium,** Washington D.C. Sponsors, AGU, IEEE Geoscience and Remote Sensing Society. (F. T. Ulaby, Remote Sensing Laboratory, Univ. of Kansas Center for Research, Inc., West Campus, Lawrence, KS 66045.)

June 14–19 Second International Conference on Urban Storm Drainage, Urbana, Ill. Sponsors, Univ. of Illinois, International Liaison in Urban Storm Drainage, International Association of Hydraulic Research, International Association of Water Pollution Research, American Society of Civil Engineers. (B. C. Yen, Department of Civil Engineering, Univ. of Illinois, Urbana, IL 61801.)

June 15–19 International IEEE/APS Symposium, National Radio Science Meeting, and International IEEE/MTT Symposium, Los Angeles, Calif. (Prof. N. G. Alexopoulos, 7732 Boelter Hall, Department of Electrical Sciences, Univ. of California, Los Angeles, CA 90024.)

June 22–26 International Symposium on Erosion and Sediment Transport Measurement, Florence, Italy. Sponsors, IAHS, International Commission on Continental Erosion, National Research Council of Italy. (P. Tacconi, Secretary of the Organizing Committee, Istituo di Ingegneria Civile Via S. Marta, 3 50139 Firenze, Italy.)

June 23–26 Seventh International Symposium on the Machine Processing of Remotely-Sensed Data, West Lafayette, Ind. Sponsor, Laboratory for Applications of Remote Sensing, Purdue Univ. (D. B. Morrison, Purdue Univ./LARS, 1220 Potter Dr., West Lafayette, IN 47906.)

June 24–26 International Symposium on Real-Time Operation of Hydrosystems, Waterloo, Ontario, Canada. Sponsor, Water Resources Group, Univ. of Waterloo. (T. E. Unny or E. A. McBean, Univ. of Waterloo, Department of Civil Engineering, Waterloo, Ontario N2L 3G1 Canada.)

June 29–July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology. (Barbara Dullea, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.)

June 29–July 3 Conference/Workshop on Heterogeneous Catalysis—Its Importance to Atmospheric Chemistry, Albany, N.Y. Sponsors, NSF, NASA. (V. A. Mohnen, Atmospheric Sciences Research Center, State Univ. of New York, Albany, NY 12222.)

June 29–July 11 Seminar on Fluid-Dynamical Problems in Astrophysics and Geophysics, Chicago, Ill. Sponsors, American Mathematical Society, Society for Industrial and Applied Mathematics. (Meeting Arrangements Department, American Mathematical Society, Post Office Box 6248, Providence, R.I.)

July 6–11 Geocongress '81-South African Geodynamics Project and 3rd International Platinum Symposium, Pretoria, South Africa. Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat S. 217, CSIR, P.O. Box 395, Pretoria 0001 Republic of South Africa.)

July 8–10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsor, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 15–17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Buchanan, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21–23 **Chapman Conference on Spatial Variability in Hydrologic Modeling,** Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

July 21–30 21st General Assembly of IASPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27–30 **Eighth International Symposium on Urban Hydrology, Hydraulics, and Sediment Control,** Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 206B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug. 3–15 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug. 4–7 International Conference on Energy Education, Providence, R.I. (Donald Kirwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9–15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, ICCL, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 9–18 International Congress of Surveyors, F.I.G., Montreux, Switzerland. Sponsor, Fédération Internationale Des Geometres. (American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 10–14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10–14 Water Forum '81: Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage. (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22044.)

Aug. 10–19 20th General Assembly of the International Union of Radio Science, Washington, D.C. (R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418.)

Aug. 17–28 Third Scientific Assembly of IAMAP with Extraordinary General Assembly, Hamburg, Federal Republic of Germany. (S. Ruttenburg, NCAR, P.O. Box 3000, Boulder, CO 80307.)

Aug. 17–18 Open Symposium on Mathematical Models of Radio Propagation, Washington, D.C. Sponsor, URSI. (J. R. Wait, Bldg. 20, Electrical Engineering Department, Univ. of Arizona, Tucson, AZ 85721.)

Aug. 17–22 Ninth International Symposium on Earth Tides, New York, N.Y. Sponsors, IAG, IUGG, Columbia Univ. (J. T. Kuo, 828 S.W. Mudd, Columbia Univ., New York, NY 10027.)

Aug. 18–21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Haigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5061.)

Aug. 20–21 Second International Symposium on Computer-Aided Seismic Analysis and Discrimination, North Dartmouth, Mass. Sponsors, Electrical Engineering Department, Southeastern Massachusetts University, IEEE Computer Society, IEEE Acoustics, Speech and Signal Processing Society. (C. H. Chen, Electrical Engineering Department, Southeastern Massachusetts University, North Dartmouth, MA 02747.)

Aug. 24–26 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodaetisk Institut. (C. C. Tscherning, International Symposium Management of Geodetic Data, Geodaetisk Institut, Gamlehave Alle 22, Charlottenlund DK-2920 Denmark.)

Aug. 24–29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (C.-E. Lund, Chairman Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 556, 22 Uppsala, Sweden.)

Aug. 25–27 The Royal Institution of Chartered Surveyors Centenary Celebration, London, England. (Representative Radlinski, American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 28–Sept. 9 Arc Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan, IAVCEI. (Daisuke Shimozuru, IAVCEI Symposium on Arc Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31–Sept 2 Third International Colloquium on Mars, Pasadena, Calif. Sponsors, NASA, Lunar and Planetary Institute, Division of Planetary Sciences of the AAS. (Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109.)

Aug. 31–Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 Munchen 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairman of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c/o LNEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7–12 Third International Symposium on Antarctic Glaciology, Columbus, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society. (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 8–12 American Society of Photogrammetry-American Congress on Surveying and Mapping Fall Convention, San Francisco, Calif. (L. W. Aggers, USGS, 345 Middlefield Road, Mail Stop 31, Menlo Park, CA 94025.)

Sept. 13–17 National Water Well Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 16–18 **Oceans '81,** Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering, AGU. (R. Nagle, Publicity Manager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 17–18 **Midwest Meeting,** Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept. 17–18 **Pacific Northwest Regional Meeting,** Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 98920.)

Sept. 20–22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 28–Oct. 10 NATO Advanced Study Institute on Chemistry of the Unpolluted and Polluted Troposphere, Corfu, Greece. (W. Jaeschke, Center of Environmental Protection, University of Frankfurt, Robert-Mayer-Str. 11, 6000 Frankfurt/Main, FRG.)

Oct. 6–8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. El-Shaarawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 11–14 Coastal Society's Seventh Annual Conference, Galveston, Tex. (N. West, Coastal Society Conference, Department of Geography and Marine Affairs, Univ. of Rhode Island, Kingston, RI 02881.)

Oct. 11–15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 446, La Habra, CA 90631.)

Oct. 13–15 Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, La. Sponsors, Louisiana Geological Survey, Department of Natural Resources; Energy Programs Office, Louisiana State University; U.S. Department of Energy. (Ann Bachman, Conference Coordinator, Energy Programs Office, 105 Hill Memorial, Louisiana State Univ., Baton Rouge, LA 70803.)

Oct. 13–16 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hapke, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14–16 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 633 Sixth Ave., S.W., Calgary, Alberta, Canada T2P 2Y5.)

Oct. 22–24 Fourth Conference on the Physics of the Jovian and Saturnian Magnetospheres, Laurel, Md. Sponsor, NASA. (S. M. Krimigis, Applied Physics Laboratory, Johns Hopkins Univ., Laurel, MD 20810.)

Oct. 26–30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shorelines Commission of the International Union for Quaternary Research, Scientific Committee of the World Confederation of Underwater Activities. (Patricia M. Masters, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

November 1–5 Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oreg. Sponsor, Estuarine Research Federation. (Jay F. Watson, Treasurer, USFWS Suite 1962, 500 N.E. Multnomah Street, Portland, OR 92232.)

Nov. 2–6 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Ames Research Center, Moffett Field, CA 94035.)

Nov. 9–11 Special Conference on the Mechanical Behavior of Salt, University Park, Pa. Sponsor, Rock Mechanics Laboratory, Department of Mineral Engineering, Pennsylvania State University. (H. Reginald Hardy, Jr., Rock Mechanics Laboratory, Room 117, Mineral Sciences Building, Pennsylvania State University, University Park, PA 16802.)

Nov. 9–20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAG, IUGG Local Committee of Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography. (R. Omandi, Survey of Kenya, P.O Box 30046, Nairobi, Kenya.)

Nov. 30–Dec. 11 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM, Research Division, Box 218, Yorktown Heights, NY 10598; or G. S. Watson, Bernoulli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08544.)

Dec. 3–5 Topical Conference on the Processes of Planetary Rifting, San Francisco, Calif. Sponsor, Lunar and Planetary Institute. (Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Dec. 7–11 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 18–19 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluva, Istituto di Petrografia, Via Gramsci 9, 43100 Parma, Italy.)

1982

Jan. 11–14 Symposium on the Understanding of Hydrologic Processes at the Basin Scale, Caracas, Venezuela. Sponsors, Universidad Simón Bolívar, IAHS. (Ignacio Rodríguez-Iturbe, Universidad Simón Bolívar, Apartado Postal 80.659, Caracas 1081, Venezuela.)

Feb. 8–12 **Third International Geodetic Symposium on Satellite Doppler Positioning**, Las Cruces, N. Mex. Sponsors, Defense Mapping Agency, National Ocean Survey, AGU. (Richard Peat, Defense Mapping Agency, Hydrographic/Topographic Center, 6500 Brooks Lane, N.W., Washington, DC 20315.)

Feb. 16–19 **Ocean Sciences AGU/ASLO (American Society of Limnology and Oceanography) Joint Meeting**, San Antonio, Tex. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Mar. 22–26 International Symposium on Hydrothermal Reactions, Yokohama, Japan. Sponsor, Tokyo Institute of Technology. (Shigeyuki Sōmiya, Research Laboratory of Engineering Materials, Tokyo Institute of Technology, Nagatsuta, Midori, Yokohama, 227 Japan.)

Apr. 11–16 Penrose Conference on Antarctica, Shenandoah National Park, Va. Sponsor, GSA. (Ian W. D. Dalziel, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY 10964.)

April 19–21 Cordilleran Section, Geological Society of America and Seismological Society of America Annual Meeting, Anaheim, Calif. (Neil Maloney, Earth Science Department, California State Univ., Fullerton, CA 92634.)

May 3–7 **14th International Liege Colloquium on Ocean Hydrodynamics**, Liège, Belgium. Sponsors IAPSO, Unesco Marine Sciences Division, EGS, Intergovernmental Oceanographic, AGU. (Jacques C. J. Nihoul, University of Liège, Mécanique des Fluides Géophysiques-Environment, B6- Sart Tilman, B-4000 Liège, Belgium.)

May 7–20 General Meeting of IAG, Tokyo, Japan. (I. Nakagawa, Geophysical Institute, Kyoto University, Sakyo-ku, Kyoto 606 Japan.)

May 10–12 Fourth International Conference on Planning and Management of Water Resources for Industrial, Agricultural, and Urban Use, Marseilles, France. Sponsors. Commission Europeenne Mediterranéenne de Planification des Eaux (C.E.M.P.E.), Société des Eaux de Marseille (S.E.M.), the Bureau de Recherches Géologiques et Minières (B.R.G.M.), Centre de Formation Internationale à la Gestion des Ressources en Eau (CEFIGRE), UNESCO, Commission des Communautés Européennes, Association des Hydrogéologues (AIH). (Secretariat de la Conference, Société des Eaux de Marseille, 25 rue Edouard Delanglade—13006 Marseille, France.)

May 24–June 4 International Solar-Terrestrial Physics Symposium, Ottawa, Ontario, Canada. (Professor Liu, University of Illinois, Urbana, IL 61801.)

May 24–June 4 24th Plenary Meeting of COSPAR, Ottawa, Ontario, Canada. (Dean Kastel, Space Sciences Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

May 25–28 **Symposium on the Composition of Nonurban Troposphere**, Williamsburg, VA. Sponsors. AMS, NASA, AGU. (Jack Fishman, Mail Stop 401-B, NASA Langley Research Center, Hampton, VA 23665.)

May 31–June 4 **AGU Spring Meeting**, Philadelphia, Pa. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

June 13–17 International Symposium on Hydrometeorology, Denver, Colo. Sponsor, American Water Resources Association. (A. I. Johnson, Woodward-Clyde Consultants, 2909 West 7th Ave., Denver, CO 80204.)

June 15–18 **International Conference on Rainwater Cistern Systems**, Honolulu, Hawaii. Sponsors, University of Hawaii's Water Resources Research Center, AGU. (Yu-Si Fok, General Conference Chairman, Water Resources Research Center, Univ. of Hawaii, 2540 Dole Street, Honolulu, HI 96822.)

June 27–July 2 Fifth International Conference on Geochronology, Cosmochronology, and Isotope Geology, Nikko National Park, Japan. (K. Shibata, Geological Survey of Japan, Higashi 1-1-3, Yatabe, Ibaraki 305 Japan.)

July 19–30 Scientific Meeting of IAHS with Extraordinary General Assembly, Exeter, United Kingdom. (John C. Rodda, Department of the Environment, Water Data Unit, Reading Bridge House, Reading RG1 8PS United Kingdom.)

Aug. 2–13 Joint Oceanographic Assembly, Halifax, Nova Scotia, Canada. Sponsor, Scientific Committee on Oceanic Research. (Leo O'Quinn, National Steering Committee for JOA, c/o Canadian Committee on Oceanography, 240 Sparks St., Ottawa, Ontario K1A 0E6 Canada.)

Aug. 15–21 Fourth International Symposium on Antarctic Earth Sciences, Ingle Farm, South Australia, Australia. Sponsors, Australian Academy of Science, Australian Academy of Technological Sciences, International Union of Geological Sciences, Scientific Committee on Antarctic Research, Geological Society of Australia, Inc., Univ. of Adelaide. (J. B. Jago, South Australian Institute of Technology, P.O. Box 1, Ingle Farm, South Australia, Australia 5098.)

Aug. 15–22 International Meeting on Generation of Major Basalt Types, Reykjavik, Iceland. Sponsors, IAVCEI, IAGC. (Basalt Meeting, c/o G. E. Sigvaldason, Nordic Volcanological Institute, 101 Reykjavik, Iceland.)

Aug. 15–22 IAVCEI and IAGC Joint Meeting, Reykjavik, Iceland. (G. E. Sigvaldason, Nordic Volcanological Institute, Univ. of Iceland, Geosciences Building, 101 Reykjavik, Iceland.)

Aug. 22–28 11th International Congress on Sedimentology, Hamilton, Ontario, Canada. Sponsor, IAS. (IAS Congress 1982, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada.)

Aug. 22–28 Third Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii. Sponsor, IUGS. (AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101.)

Aug. 23–27 Ninth Annual Meeting of the European Geophysical Society, Leeds, United Kingdom. (J. C. Briden, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, England.)

Aug. 23–27 Second Symposium on Applied Glaciology, Hanover, N.H. Sponsor, International Glaciology Society. (Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom.)

Sept. Third International Kimberlite Conference, Clermont-Ferrand, France. (Françoise Boudier, Université de Nantes, Laboratoire de Tectonophysique, 2 Rue de la Houssinière, 44072 Nantes, France.)

May or Sept. Scientific Meeting of IAPSO, Halifax, Canada. (E. C. LaFond, LaFond Oceanic Consultants, P.O. Box 7325, San Diego, CA 92017.)

Dec. 6–10 **AGU Fall Meeting**, San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

1983

July 18–23 Fourth International Conference on Permafrost, Fairbanks, Alaska. Sponsors, National Academy of Sciences, State of Alaska. (L. De Goes, Polar Research Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

Aug. 15–26 18th General Assembly of IUGG, Hamburg, Federal Republic of Germany. (P. Melchior, Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180 Bruxelles, Belgium.)

Aug. 27 Symposium Commemorating the 100th Anniversary of the Mount Krakatau Eruption, Jakarta, Indonesia. Sponsor, Indonesian Institute of Sciences. (Didin Sastrapradja, Deputy Chairman for Natural Sciences, L1P1 JL, Teuku Chik Ditiro 43, Jakarta, Indonesia.)

Sept. 12–14 National Water Well Association 35th Annual Convention and Exposition, St. Louis, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Dec. 5–9 **AGU Fall Meeting**, San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

FUTURE AGU MEETINGS

Fall Meetings
December 7–11, 1981, San Francisco
December 6–10, 1982, San Francisco
December 5–9, 1983, San Francisco

Spring Meetings
May 31–June 4, 1982, Philadelphia

AAPG American Association of Petroleum Geologists
AMS American Meteorological Society
ASCE American Society of Civil Engineers
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHS International Association for Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association of Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science

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Hydrology

3110 Erosion and Sedimentation
UNSTEADY ONE-DIMENSIONAL SETTLING OF SUSPENDED SEDIMENT
S. Dhamotharan, J. S. Gulliver, H. G. Stefan (St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minnesota 55414)
A one-dimensional, unsteady numerical model for the vertical distribution of suspended sediment concentration and rate of suspended sediment deposition in shallow water stirred uniformly has been developed. The advection/diffusion equation is solved by a fully implicit, exponential finite difference scheme. The computations are unconditionally stable regardless of Peclet number Pe = Vh/D, where V = particle fall velocity, h = depth, and D = vertical turbulent exchange coefficient. The model is presented; error criteria for selection of depth and time steps are given. A comparison between a numerical solution and an exact analytical solution is given for an instantaneous injection. A generic study of suspended sediment concentration profiles as a function of depth and time and for various Peclet numbers has been made and results are given in dimensionless graphical form. (Suspended sediment, numerical model, lake water, particles).
Water Resour. Res., Paper 1W0472

3110 Erosion and Sedimentation
CHANNEL INSTABILITY IN A BRAIDED, SAND-BED RIVER
W.L. Graf (Department of Geography, Arizona State University, Tempe, Arizona, 85281)
The Gila River of central Arizona is representative of braided, sand-bed rivers in alluvial valleys that have inherent unstable behavior and destructive channel migration. The 112-year record of channel conditions along a portion of the Gila River provides data for the construction of locational probability maps for main-flow channels. Zones of stability and hazardous instability alternate with each other at 3.2 km (2 mi) intervals. During the past century, the overall sinuosity of the main flow channel has remained close to 1.8 despite numerous changes in subreaches as a result of sedimentation behind a dam and fluctuations in the density of phreatophyte growth, which both affect the hydraulics of flood flows. Unstable zones of the channel correspond to the surface of the sediment wedge behind the dam and areas dense phreatophyte growth. Stable zones correspond to areas controlled by bedrock or man-made structures, as well as locations determined by these external factors plus the requirement to maintain a consistent sinuosity. Channels such as that of the Gila River do not meet most assumptions of equilibrium, and are best understood through probabilistic approaches with an assumption of catastrophic adjustment. (Fluvial processes, phreatophytes, braided channels).
Water Resour. Res., Paper 1W0584

3125 Glaciology
A DETAILED STUDY OF SNOW ACCUMULATION AND STABLE ISOTOPE CONTENT IN THE DOME C (ANTARCTICA)
J.R. Petit (Laboratoire de Glaciologie, CNRS 2, rue Très-Cloîtres, 38031 Grenoble Cedex France) J. Jouzel, M. Pourchet and L. Merlivat
Snow samples have been taken in the Dome C area with the purpose to study the variations of the accumulation rate and of the stable isotope content over the last century. Stakes observations indicate a large spatial variability of the accumulation rate at a one year scale (σ = 2.6 g/cm²/yr for a mean value = 3.6 g/cm²/yr). The depth of the 1965 and 1955 layers determined from beta radioactivity measurements in 19 sites allows to deduce that the spatial variability becomes small at a ten year scale (σ = 0.3/cm² per year) showing that the snow collected at one point is well representative of the fallen precipitation over this period. The rate of snow accumulation since 1965 is about 30% higher than during the 1955-1965 period. This conclusion is supported by measurements over a large geographical sector of East Antarctica.
Shorter term changes of the snow accumulation have been studied by various means and in particular from detailed deuterium content profiles; by comparing with the beta and tritium radioactivity determinations it is shown that the deuterium variations do not allow to obtain a seasonal record. In such a low accumulation area different mechanisms (such as smoothing of the isotopic signal, roughness of the surface, irregularity of the accumulation) which may disturb the short term record are discussed.
The interpretation of stratigraphic observations is not straightforward. However it was possible to obtain a calibration down to the 1955 layer which allows to offer a dating of snow layers over the last 100 years. The mean accumulation so obtained (3.7 g/cm²/yr) is in good agreement with the value (3.6 ± 0.3) deduced from lead 210 measurements.
Geographical changes of the mean deuterium content are relatively small showing that at a ten scale the isotopic signal is well representative of the mean deuterium content of the precipitation. This ensures that the smoothed (ten years running mean values) deuterium profile obtained over the last 100 years provides a good indication of the temperature secular trend in the Dome C area. (Snow accumulation, stable isotopes in snow, snow stratigraphy, radioactive fallout)
J. Geophys. Res., Green, Paper 1C0715

3130 Groundwater
TRANSPORT OF ION-EXCHANGING SOLUTES IN GROUNDWATER: CHROMATOGRAPHIC THEORY AND FIELD SIMULATION
A. Valocchi, R. Street (Department of Civil Engineering, Stanford, California 94305) and P. Roberts
Equations describing the transport of ion-exchanging solutes governed by local chemical equilibrium through a saturated porous medium are well established in the literature. Concentration profiles resulting from the numerical solution of the general multi-species equations typically exhibit unusual and complicated features, such as multiple fronts and plateau zones. This paper presents an analytical framework, based upon the theory of chromatography, which permits a priori characterization of certain key concentration profile features. The cases studied include both homovalent and heterovalent exchange in binary and ternary systems. In order to test the validity, the chromatographic analysis is applied to a field project involving direct injection of advanced-treated municipal effluent into an aquifer. All of the major features observed in the available field data are accurately predicted by the chromatographic theory. (Groundwater, ion-exchange, chromatography, porous media).
Water Resour. Res., Paper 1W0777

3130 Groundwater
A COMPARISON OF THE INCOMPLETE CHOLESKY-CONJUGATE GRADIENT METHOD WITH THE STRONGLY IMPLICIT METHOD AS APPLIED TO THE SOLUTION OF TWO-DIMENSIONAL GROUNDWATER FLOW EQUATIONS
L. K. Kuiper (U.S. Geological Survey, Huron, South Dakota 57350)
This paper compares the efficiency of the strongly implicit procedure (SIP) and the incomplete Cholesky-conjugate gradient method (ICCG) applied to the solution of the finite-difference approximating equations for groundwater flow. Results for five isotropic two-dimensional test problems are presented. Three are linear confined-aquifer problems, and two are nonlinear water-table aquifer problems. In all but one of the test problems the aquifer was considered to be nonhomogeneous. Both SIP and ICCG as applied to water-table aquifer problems make use of iteration parameters. These were varied for each of the test problems to reduce the amount of computational work needed to find a solution. ICCG was usually substantially more efficient than SIP when applied to the confined-aquifer test problems. For the water-table aquifer test problems, SIP and ICCG performed equally well.
Water Resour. Res., Paper 1W0716

3130 Groundwater
EFFECT OF SIZE ON FLUID MOVEMENT IN ROCK FRACTURES
Paul A. Witherspoon (Lawrence Berkeley Laboratory and Department of Materials Science and Mineral Engineering, University of California, Berkeley, 94720)
Laboratory studies on fluid flow in single fractures in rock samples up to a meter in size suggest that there is a definite problem of scale. Two such studies have been reported, but the results are not consistent. [illegible]
Geophys. Res. Lett., Paper 1L0624

3130 Groundwater
STEADY PERIODIC FLOW THROUGH A RECTANGULAR DAM
J.H. Knight (Division of Mathematics and Statistics, CSIRO, P.O. Box 218, Lindfield, NSW 2070, Australia)
For unsteady free surface flow through a rectangular porous dam, a simple relation which connects a pressure integral with the movement of the free surface is derived. For steady periodic movement driven by oscillating reservoir levels, the time average of the pressure integral leads to an average discharge formula which is a generalization of the Dupuit-Forchheimer discharge formula. For periodic fluctuations of groundwater in a shallow coastal aquifer in response to tidal oscillations, it is shown that the equilibrium free surface level far from the sea is equal to the root mean square of the sea level, independent of the validity of the Dupuit-Forchheimer assumptions used by Philip. (Groundwater flow, free surface, Dupuit-Forchheimer theory, tidal effects).
Water Resour. Res., Paper 1W0499

3130 Groundwater
ANALYSIS OF FLOW THROUGH HETEROGENEOUS RANDOM AQUIFERS BY THE METHOD OF EMBEDDING MATRIX. PART 1. STEADY FLOW
G. Dagan (School of Engineering, Tel-Aviv University Tel-Aviv, Israel)
The statistical structures of the hydraulic conductivity, head gradient, specific discharge and head fields are analyzed with the aid of a simplified model consisting of a collection of spherical (in three dimensions) and cylindrical (in two dimensions) blocks of different conductivity and diameter set at random and independently in space. Results of a previous work for the effective conductivity and embedding matrix (Dagan, 1979) are recovered and given a rational derivation. The influence of the aquifer boundary [illegible] with distance from boundary in two-dimensional flows is compared with that of Monte-Carlo simulations of Smith and Freeze (1979).
Water Resour. Res., Paper 1W0164

3130 Groundwater
THE STATISTICAL MECHANICAL THEORY OF GROUNDWATER FLOW
G. Sposito (Dept. of Soil and Environ. Sciences, University of California, Riverside 92521) S.-Y. Chu
The macroscopic differential equations of mass, linear momentum, and energy balance for groundwater are derived from first principles by using the methods of statistical mechanics. [illegible]

3150 Precipitation
SOME LIMITING FORMS OF THE POISSON DISTRIBUTION OF ANNUAL STATION PRECIPITATION
P. S. Eagleson (Massachusetts Institute of Technology, Cambridge, Massachusetts 02139 USA)
Annual station precipitation is represented as a seasonally-stationary Poisson arrival process in terms of three constituent random variables, storm length, number of storms, and storm depth, and the distribution of the annual total is derived. The contribution of each constituent variable to variance of the annual total precipitation is determined and limiting distributions of the latter are derived by letting each contribution vanish separately. In humid climates, it is shown that the storm depth variability predominates giving a distribution which is closely normal. In arid climates, the number of storms controls and gives a highly-skewed distribution. All cases are compared with observations.
Water Resour. Res., Paper 1W0249

3160 Hydrology: Run-off and streamflow
DETERMINATION OF THE CONFIDENCE INTERVALS OF THE WEIBULL DISTRIBUTION USING ORDER STATISTICS
B. Bobée (Université du Québec, INRS-Eau, C.P. 7500, Ste-Foy, Québec, Canada) P. Boucher
Recent results show the interest of the Weibull distribution to represent flood flows. It is possible to determine in an explicit fashion the distribution of the order statistics for the Weibull distribution. The determination of the confidence intervals for a given level of an event of return period T is deduced when the Weibull distribution is fitted to a sample of size N. This general procedure is valid for all estimation methods of the parameters of the Weibull distribution and gives a good approximation.
Water Resour. Res., Paper 1W0243

3160 Runoff and streamflow
ESTIMATION OF EXTREME LOW FLOWS FOR PUMPED STORAGE RESERVOIR DESIGN
A. V. Metcalfe (Department of Engineering Mathematics, The University, Newcastle upon Tyne, England) and J. A. Mawdsley
A method for estimating the probability of non-exceedance of low flows for a reservoir fed directly by one river with additional pumped inflow from a second river is described. The method is based on the joint probability distribution of an extreme value distribution and a truncated extreme value distribution. The estimates of the probabilities of given low flows are given by integrals. These are evaluated numerically for a range of low flows and maximum daily pumping rates. Details are given for the particular case of total inflow during a three consecutive month period, but the method could be used for any duration. (Low flows, reservoir, pumped storage, joint probability distribution.)
Water Resour. Res., Paper 1W0655

3160 Runoff and streamflow
REGIONAL FLOOD FREQUENCY ESTIMATION AND NETWORK DESIGN
Karl V. Greis and Eric F. Wood (Department of Civil Engineering, Princeton University, Princeton, NJ 08544)
The use of probability weighted moments has been investigated for improving estimates of flood recurrence quantile events in both gauged and ungauged basins. Regional estimates at gauged sites are improved over more conventional methods such as method of moments and maximum likelihood estimation. An improved method for ungauged basins is proposed which incorporates both probability weighted moment techniques with more traditional mean peak flow estimation. The question of network design, in terms of number of sites and number of years of record is re-examined in light of the probability weighted moment techniques. (Network design, regional flood frequency, probability weighted moments).
Water Resour. Res., Paper 1W0515

3160 Runoff and streamflow
PROCEDURES FOR FLOOD LEVEE DESIGN
Y.-K. Tung (Dept. of Civil Engr., University of Nevada, Reno, Nevada) and L. W. Mays (Department of Civil Engr., University of Texas, Austin, Texas)
In the design of flood levee systems there are many parameters and variables with associated uncertainties. This paper presents models which systematically analyze the various types of uncertainties in the hydrologic aspect as well as hydraulic aspect of design and analysis to define the risk and reliability of overtopping. Both static and time dependent risk models are developed. Results show that risks evaluated by the simple return period method can be underestimated by 10% to 30%, depending on the loading distribution model used. The risk-safety factor relationships are shown to be very sensitive to the hydrologic loading probability model adopted, so that composite models are suggested for risk analysis.
Water Resour. Res., Paper 1W0502

3160 Runoff and streamflow
DRAINAGE NETWORK STRUCTURE AND THE DIAMETER-MAGNITUDE RELATION
R. Jarvis (Department of Geography, State University of New York at Buffalo, 415 Fronczak Hall, Buffalo, New York 14260) and C. Sham
Drainage network structure can be described in terms of elongation or compaction, using the network diameter and magnitude. The relation between network diameter and magnitude is the topologic equivalent of the well-known relation between mainstream length and drainage basin area. Diameter increases with magnitude, but at a decreasing rate as networks are sampled over a greater size range. [illegible] The sequence of tributary magnitudes down a mainstream is not random. Large tributaries pre-empt drainage area, and tend to be followed downstream by a number of small tributaries. In fluvial landscapes free from geological constraints, networks tend to become relatively more elongate with increasing size downstream.
Water Resour. Res., Paper 1W0477

3170 Snow and ice
FRACTURE MECHANICAL MODELS OF DRY SLAB AVALANCHE RELEASE
David M. McClung (Division of Building Research, National Research Council, 3904 West 4th Avenue, Vancouver, B.C. V6R 1P5)
Experimental evidence shows that snow in a natural [illegible]
J. Geophys. Res., Red, Paper 1B0839

3175 Soil moisture
IMPROVED LINEAR TRIAL FUNCTION FINITE ELEMENT MODEL OF SOIL MOISTURE TRANSPORT
[illegible] (University of California, Irvine)
[illegible]
Water Resour. Res., Paper 1W0690

3175 Soil moisture
CANOPY TEMPERATURE AS A CROP WATER STRESS INDICATOR
R. D. Jackson (U. S. Water Conservation Laboratory, 4331 E. Broadway Rd., Phoenix, Arizona 85040), S. B. Idso, R. J. Reginato, and P. J. Pinter, Jr.
Canopy temperatures, obtained by infrared thermometry, along with wet- and dry-bulb air temperatures and an estimate of net radiation were used in equations derived from energy balance considerations to calculate a crop water stress index (CWSI). Theoretical limits were developed for the canopy-air temperature difference as related to the air vapor pressure deficit. The CWSI was shown to be equal to 1 - E/Ep, the ratio of actual to potential evapotranspiration obtained from the Penman-Monteith equation. Four experimental plots, planted to wheat, received post-emergence irrigations at different times to create different degrees of water stress. Pertinent variables were measured between 1340 and 1400 each day (except some weekends). The CWSI, plotted as a function of time, closely paralleled a plot of the extractable soil water in the 0- to 1.1-m zone. Usefulness and limitations of the index are discussed. (Water stress, soil moisture, plant canopy temperature, infrared thermometry).
Water Resour. Res., Paper 1W0449

3175 Soil Moisture
STATISTICAL ANALYSIS OF THE BROOKS-COREY AND THE GREEN-AMPT PARAMETERS ACROSS SOIL TEXTURES
R. R. McCuen, W. J. Rawls (USDA-SEA, Building 007, BARC-West, Beltsville, Maryland 20705) and D. L. Brakensiek
Infiltration is a major component of the hydrologic cycle for most watersheds. Therefore, it is important to have a method that can provide infiltration estimates for soils within ungaged watersheds. Both the analysis of variance and the multivariate analysis were used to examine whether estimated Brooks-Corey and Green-Ampt parameters differ singularly or collectively across soil texture classes. The analysis indicated that the parameters for the two models examined varied collectively across soil texture classes. Mean parameter values and standard errors for soil textures are presented for possible use on ungaged watersheds.
Water Resour. Res., Paper 1W0476

3175 Soil moisture
TWO-DIMENSIONAL SOIL MOISTURE FLOW IN A SLOPING RECTANGULAR REGION; EXPERIMENTAL AND NUMERICAL STUDIES
J. L. Nieber (Department of Agricultural Engineering, Texas A&M University, College Station, Texas 77843) and R. F. Walter
Results from experiments with a 3.66 meter by 0.58 meter by 0.108 meter flume filled with sand are used to study the two-dimensional flow of soil moisture under the condition of rainfall infiltration. The experimental results are compared to results obtained by a numerical solution (via a finite element-finite difference transformation) of the two-dimensional Richards equation. The results are presented in the form of flow field conditions (hydraulic head distribution and position of the phreatic surface) and the rising limb of the runoff hydrograph. The experimental and the numerical results are in satisfactory agreement when the effect of capillary hysteresis is incorporated into the numerical solution. When capillary hysteresis is ignored the numerically simulated hydrograph lags far behind the experimentally derived hydrograph. (Soil moisture flow, capillary hysteresis).
Water Resour. Res., Paper 1W0696

3175 Soil moisture
APPORTIONMENT OF NET RECHARGE IN LANDFILL COVERING LAYER INTO SEPARATE COMPONENTS OF VERTICAL LEAKAGE AND HORIZONTAL SEEPAGE
John J. Lentz (Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland 20810, USA)
Surplus soil moisture in a sloping landfill covering layer is apportioned into a vertical leakage fraction and a horizontal seepage fraction by assuming vertical flow equal to the hydraulic conductivity of the waste and Darcian horizontal flow through a varying vertical cross-section at a velocity determined by the hydraulic conductivity of the cover layer and a gradient equal to the slope of the interface between the cover layer and the waste. The governing equation is set up by input-output analysis, and differentiates into the Boussinesq equation. The resulting partial differential equation is solved by linearization. A solved numerical example is given.
Water Resour. Res., Paper 1W0695

3180 Water quality
METAL ION CONCENTRATIONS ASSOCIATED WITH LATE SUMMER SEDIMENTS OF THE OHIO RIVER
H.T. Spencer (Department of Chemical and Environmental Engineering, Speed Scientific School, University of Louisville, Louisville, Kentucky, USA) C.A. Lauchart, and R.S. Colyer
The fine late summer sediments of the McAlpine pool of the Ohio River are described as composed of an average 3% by dry weight volatile solids material. The volatile solids component was found to be associated with virtually all of the COD, hydrogen, sodium, potassium, aluminum, manganese, and lead, as well as a significant portion of the carbon, chromium, iron, copper, and zinc. Magnesium was found to have all of its acid soluble component associated with the nonvolatile portion of the sediment. The ambient thorium and uranium concentration was found to be 11.0 ± 0.8 and 1.4 ± 0.3 ug g⁻¹, respectively. The potential effect of this late summer sediment on aquatic life is suggested. (Metal ions, river sediments, Ohio River).
Water Resour. Res., Paper 1W0193

3190 Instruments and techniques
SIMPLE IN-SITU DETERMINATION OF HYDRAULIC CONDUCTIVITY BY POWER-FUNCTION DESCRIPTIONS OF DRAINAGE
She-Kong Chong, Richard E. Green (Hawaii Institute of Tropical Agriculture and Human Resources, and Water Resources Research Center, University of Hawaii, Honolulu, Hawaii) and Lajpat R. Ahuja
Equations for calculating hydraulic conductivity functions K(θ) and K(h), where θ is volumetric water content and h is soil water pressure head, were derived with the assumption of unit hydraulic gradient. The derivation employed power functions to describe the change in θ and h with time during the redistribution period following steady infiltration. The unit gradient assumption was found to be satisfied during intermediate stages of drainage but not at early and late times (i.e. high and low water contents). However, deviations from unit gradient did not cause serious errors in the calculated conductivity on the test soils, well drained oxisols which evidence a decrease in conductivity with depth at field saturation. (Hydraulic conductivity, unsaturated soils, infiltration, drainage, oxisols, soil water methods).
Water Resour. Res., Paper 1W0656

3190 Hydrology - Instruments and techniques
A SURVEY OF MATHEMATICAL OPTIMIZATION MODELS AND ALGORITHMS FOR DESIGNING AND EXTENDING IRRIGATION AND WASTEWATER NETWORKS
Christoph E. Mandl (Institute for Advanced Studies, Stumpergasse 56, A-1060 Vienna, Austria)
This paper presents a state-of-the-art survey of network models and algorithms that can be used as a planning tool in irrigation and wastewater systems. It is shown that the problem of designing or extending such systems basically leads to the same type of mathematical optimization model. The difficulty in solving this model lies mainly in the properties of the objective function. Trying to minimize construction and/or operating costs of a system typically results in a concave cost (objective) function, due to economies of scale. A number of ways to attack such models are discussed and compared, including linear programming, integer programming and specially designed exact and heuristic algorithms. The usefulness of each approach is evaluated in terms of the validity of the model, the computational complexity of the algorithm, the properties of the solution, the availability of software and the capability for sensitivity analysis. (Optimization, survey, irrigation, wastewater).
Water Resour. Res., Paper 1W0525

3199 General or miscellaneous
THE IRRIGATION SCHEDULING PROBLEM AND EVAPOTRANSPIRATION UNCERTAINTY
A.E. Bhamala, R.L. Bras (Massachusetts Institute of Technology, Cambridge, Massachusetts 02139)
Scheduling and determining irrigation water applications is an important consideration given limited water resources and increasing concern about agricultural productivity. Past literature has repeatedly been concerned with the influence of the variability of actual evapotranspiration on crop irrigation needs. This work investigates the above issue. A model, based on Stochastic Dynamic Programming, is formulated to maximize net benefits from a crop facing uncertain, correlated, evapotranspiration demands. Weekly irrigation decisions are made after observing current soil moisture and available irrigation water, as well as potential evapotranspiration in the past week. The model is similar to the traditional reservoir control algorithms popular in the surface water literature. A case study example indicates that although the model formulation is useful and feasible, the effect of uncertain evapotranspiration on irrigation performance measures is apparently minimal. (Irrigation, evapotranspiration, dynamic programming).
Water Resour. Res., Paper 1W0731

3199 General or miscellaneous hydrology
THE EFFECT OF COLD WATER ENTRY INTO A LIQUID-DOMINATED TWO-PHASE GEOTHERMAL RESERVOIR
Malcolm A. Grant (Applied Mathematics Division, DSIR, Box 1335 Wellington, New Zealand)
The effect of fluid withdrawal and injection into a two-phase geothermal reservoir is considered. The geothermal reservoir matrix is modelled as a homogeneous porous medium, except that fracturing ensures that injected fluid mixes fully into two-phase fluid. Withdrawal of fluid causes a pressure drop. Injection of fluid causes a pressure change dependent on the fluid enthalpy and rate of injection; nearly always a pressure drop for cold fluid injection. In addition to the pressure disturbance travelling away from the point of injection, there is a change in saturation near the injection point that travels away vertically. Natural perturbations might introduce cold water into a reservoir by lateral flow. To stabilise the two-phase fluid by eliminating the advance of such intrusion a stability criterion is derived. This is shown to be approximately satisfied by observed pressures in several fields.
Water Resour. Res., Paper 1W0499

Meteorology

3705 Air quality
TIME SERIES SEARCH FOR TREND IN TOTAL OZONE MEASUREMENTS
[illegible]
Time series analysis of monthly average total ozone measurements at 37 Dobson stations throughout the world shows no ozone depletion has occurred at these stations through 1979. The trends at the 14 stations with records from 1958-1979 show [illegible]. The average change is the sum of all long term global trends. The confidence limits are calculated from the variation among stations and include all effects that differ from station to station. A comprehensive evaluation of model adequacy indicated that variations in the statistical methodology have only small effects on the results. Addition of known trends to the data showed trends would be detected if present. The uncertainty in the observed average change decreases with each year's new data. It is concluded that a depletion half that hypothesized by current atmospheric models as due to chlorofluorocarbons (CFC's) would be detected. These stations provide a good early warning of any depletion that might be due to CFC's.
J. Geophys. Res., Green, Paper 1C0787

3715 Chemical composition and chemical interactions
ATMOSPHERIC CARBON DIOXIDE AND CHLOROFLUOROMETHANES: COMBINED EFFECTS ON STRATOSPHERIC OZONE, TEMPERATURE, AND SURFACE TEMPERATURE
L. B. Callis (NASA Langley Research Center, Hampton, Virginia 23665) Murali Natarajan
Time-dependent release scenarios for carbon dioxide and chlorofluoromethanes (CF_2Cl_2, $CFCl_3$) are assumed. The combined effects on stratospheric ozone and temperature are examined with a time-dependent radiative-convective-photochemical model. A steady-state version of the model is used to determine surface temperature effects and to establish asymptotic levels. Results indicate the following: (1) The total ozone time history is significantly different from that due to the chlorofluoromethanes alone; (2) A local ozone minimum occurs in the upper stratosphere about 45 years from the present with a subsequent ozone increase, then decline; and (3) Steady-state solutions indicate that tropospheric temperature and water vapor increases, associated with increased infrared opacity, cause significant changes in tropospheric ozone levels for 2 x CO_2 and 4 x CO_2 with and without the addition of chlorofluoromethanes. (Tropospheric ozone, greenhouse effect, CO_2).
Geophys. Res. Lett., Paper 1L0804

3715 Chemical composition and chemical interactions
THE DISTRIBUTION OF CARBON MONOXIDE AND OZONE IN THE FREE TROPOSPHERE
W. Seiler (Max Planck Institute for Chemistry, Saarstrasse 23, D6500 Mainz, Federal Republic of Germany) J. Fishman
The two-dimensional distributions of CO and O_3 in the free troposphere during July and August 1974 are discussed. The data confirm the previous findings that both of these gases are considerably more abundant in the Northern Hemisphere, but the degree of the asymmetry is somewhat different from what had been reported previously, especially for CO. When examined with respect to other available data sets, the conclusion is drawn that a pronounced seasonal cycle exists for CO in both hemispheres which may be driven by the likely seasonal cycle of the OH radical. The data also indicate that CO concentrations exhibit significant variability with height in the Northern Hemisphere whereas southern hemispheric concentrations are quite constant with altitude except in cases where interhemispheric exchange of air may be occurring. A discussion on the vertical and horizontal transport processes inferred from the CO and O_3 measurements is presented. The observations indicate that the region between 30 N and 40 N is very active photochemically. It is at these latitudes where the OH concentrations may be the highest during this time of the year, resulting in an area where the CO destruction rate and the rate of in-situ tropospheric ozone production may be the greatest. (Carbon monoxide, ozone, tropospheric chemistry.)
J. Geophys. Res., Green, Paper 1C0786

3735 Electrical Phenomena
BALLOON BORNE MEASUREMENTS OF THE SMALL ION CONCENTRATION
J. M. Rosen (Department of Physics and Astronomy, University of Wyoming, Laramie, Wyo. 82071) and [illegible]
Balloon borne measurements of the small ion concentration were made using a Gerdien condenser. The instrument differs from others in that a lobe pump was used to draw air through the ion collector thus insuring a well known and constant flow rate. The profiles were found to be quite repeatable over a two year period (1977-1979). In contrast to previous data, the new profiles are much smoother and show only a small decline in concentration above the ion density maximum. It is believed that this discrepancy can be attributed to a poorly known and variable flow rate in the older instruments.
J. Geophys. Res., Green, Paper 1C0755

3755 Interaction of atmosphere with electromagnetic waves
EARTH RADIATION BUDGETS
G. Stephens (Dept. of Atmospheric Science, Colorado State University and CSIRO Division of Atmospheric Physics, Australia), G. Campbell and T. Vonder Haar
The paper presents the annual and seasonal averaged earth atmosphere radiation budgets derived from the most complete set of satellite observations available in late 1978. The budgets are derived from a composite of 48 monthly mean radiation budget maps. The annual, global average emitted infrared flux is 234 W.m⁻², planetary albedo is 0.30 and the net flux is zero within measurement uncertainty. The annual cycle of net flux is also studied in detail and the observed globally averaged net flux displays an annual cycle which is similar in phase and magnitude to the annual cycle imposed by the influence of sun earth distance variations on solar radiation input into the atmosphere. A study of the geographical distribution of the annual variability of the net flux reveals that generally greater than 95% of this variability occurs as a result of the semi and annual cycles which may be forced by the regular variation of solar declination throughout the year. However, the amounts of energy contained in the variance from year to year is large. Radiative transfer model simulations of the observed budget quantities at the "top-of-the-atmosphere" are presented and agree with observation at least for the zonally averaged case. Significant differences exist between the present surface radiation budget calculations to those previously estimated. The differences, largely a result of the exclusion of enhanced absorption in the window region (8-14 μm) in earlier budget calculations, provide some 35 W.m⁻² more radiant energy into the oceans in the tropics than previously estimated. The validity of this result was verified using GATE radiation budget measurements.
J. Geophys. Res., Green, Paper 1C0608

4230 Experimental mineralogy and petrology
PARTITIONING OF REE BETWEEN MINERALS AND COEXISTING MELTS DURING PARTIAL MELTING OF A GARNET LHERZOLITE
Wendy J. Harrison (SN6-NASA Johnson Space Center, Houston, TX 77058)

... and b) for Ce, Sm, and Tm between garnet, clinopyroxene, orthopyroxene, olivine, and melt have been determined at 35 kbar for 2.3, 8, 20, and 37.7% melting of a garnet lherzolite nodule with chondritic REE abundances. Partition coefficients increase as the degree of partial melting increases. From 2.3 to 8% melting, this increase is largely a consequence of non-Henry's law behavior of REE in minerals. At melt percentages ≥9%, changing temperature and melt composition, as well as non-Henry's law behavior, also influence the values of REE partition coefficients. The total increase in D_{REE} crystal/melt from 2 to 38% melt may be up to 100% for some minerals and REE, and the assumption made in petrogenetic modeling of constant partition coefficients is therefore questioned.

Experimentally determined REE abundances in the 2.3 and 8% melts can be adequately modeled with an equilibrium partial melting model and a melting reaction, determined by Mysen (1977a), in the system $CaO-MgO-Al_2O_3-SiO_2$:

garnet + 0.67 diopside + 0.14 enstatite⊕0.22 forsterite + 1.61 liquid.

REE abundances cannot be calculated at higher percentages of melting because the melting reaction is not known.

The LREE enrichment in the 2.3% melt is 22 times chondritic abundance, and this melt has chondrite-normalized Ce/Tm = 4.18. The generation of REE abundances typical of most alkali basalts (Ce enrichment 40-200 and Ce/Tm 2-16) is not possible even by low percentages of partial melting of a garnet lherzolite unless the material has been enriched in LREE relative to chondrites.

Am. Mineralogist, 66, 3-4

4230 Experimental mineralogy and petrology
PHASE RELATIONS OF TUNGSTATE MINERALS UNDER HYDROTHERMAL CONDITIONS
L. C. Hsu (Nevada Bureau of Mines-Geology and Dept. of Geological Sciences, Mackay School of Mines, University of Nevada, Reno, NV 89557)

The binary phase relations of several naturally occurring tungstate minerals, of the general form $M^{2+}WO_4$, were investigated hydrothermally at fluid pressure of 1.0 kbar and temperatures of 400°C to 900°C. A complete solid solution, with ...

Mineralogy, Petrology, and Crystal Chemistry

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5720 Interactions between solar wind and magnetosphere
OBSERVATIONS OF EFFECTS FROM MAGNETOSPHERIC CUSP MOVEMENT DURING A SOLAR PROTON EVENT
R. R. Brown (Department of Physics, University of California, Berkeley, CA. 94720) J. R. Barcus, P. Stauning and E. N. Faraa

The interplanetary magnetic field underwent a strong southward turning at the location of the ISEE-3 spacecraft, with B_z (in satellite coordinates) decreasing from +15γ to −15γ in the interval from 1540 UT to 1600 UT on August 20, 1979. Solar wind speed measurements at the spacecraft indicated that the southward turning of the IMF should have reached the front of the magnetosphere around 1625 UT. At that time the solar proton event of August 18, 1979 was still in progress. Observations from balloon-borne and ground-based instrumentation in Greenland in that period, around 1615 magnetic local time, showed an expansion of the polar cap, the cusp moving southward by at least 5 degrees in latitude in 15 minutes, starting around 1635 UT. From changes in the energetic photon spectrum at balloon-altitude, it is shown that the proton cutoff energy at Søndre Strømfjord, Greenland prior to the cusp motion was in the range 6-10 MeV. (Magnetospheric cusp, movement, solar proton event).
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PLASMA SHEET MOTIONS INFERRED FROM MEDIUM ENERGY ION MEASUREMENTS
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Medium energy ions measured by ISEE-2 are used to provide information on plasma sheet motions during expansions following substorm. The upwards speed of the plasma sheet edge measured locally is commonly 50 km/s. It is thought ...